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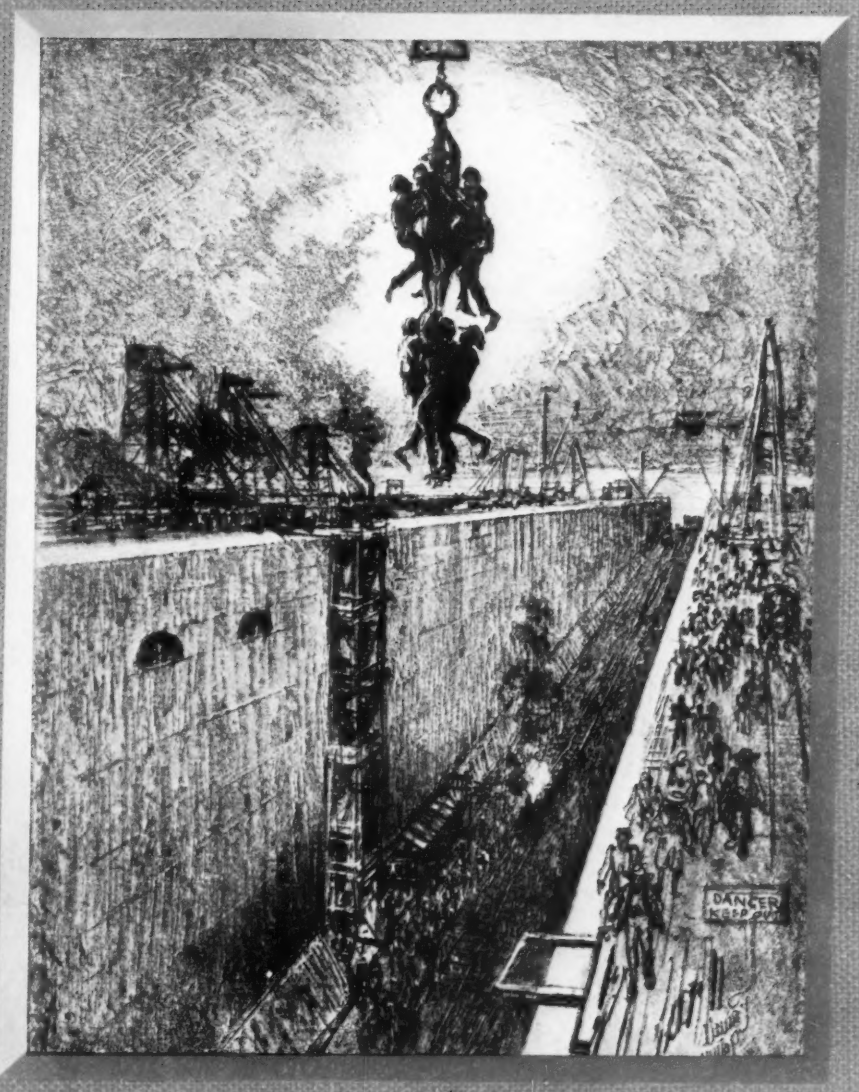

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VOLUME IX, NO. 6
NOVEMBER, 1928

POWER PLANTS

ONE MILLION K.W. is the ultimate capacity of the Central Station shown at the top of the page. The Laundry, illustrated below, operates a 70 h.p. boiler.

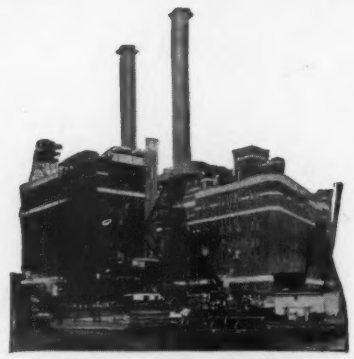
Both plants are equipped with fuel burning apparatus, designed, manufactured and installed by Combustion Engineering Corporation.

There is no sharp dividing line between the responsibilities of the stoker or burner manufacturer, the furnace builder and the boiler maker. Steam Generation is a combined process of heat liberation and heat absorption. The performance of individual elements is secondary to the performance of the combination —*as a unit.* The ultimate goal sought is to produce a dependable supply of steam at minimum cost.

The operation of the Laundry is dependent upon the performance of this 70 h.p. boiler, while thousands of New Yorkers rely upon the East River Station for light, power, transportation and the many material comforts of life which electricity has made available.

The engineering, research and manufacturing facilities of Combustion Engineering Corporation are available to American Industry in raising the standards of Fuel Burning and Steam Generation, throughout the entire range from 70 h.p. to 1,000,000 K.W.—*or beyond.*

A 70 h. p. boiler serves this laundry



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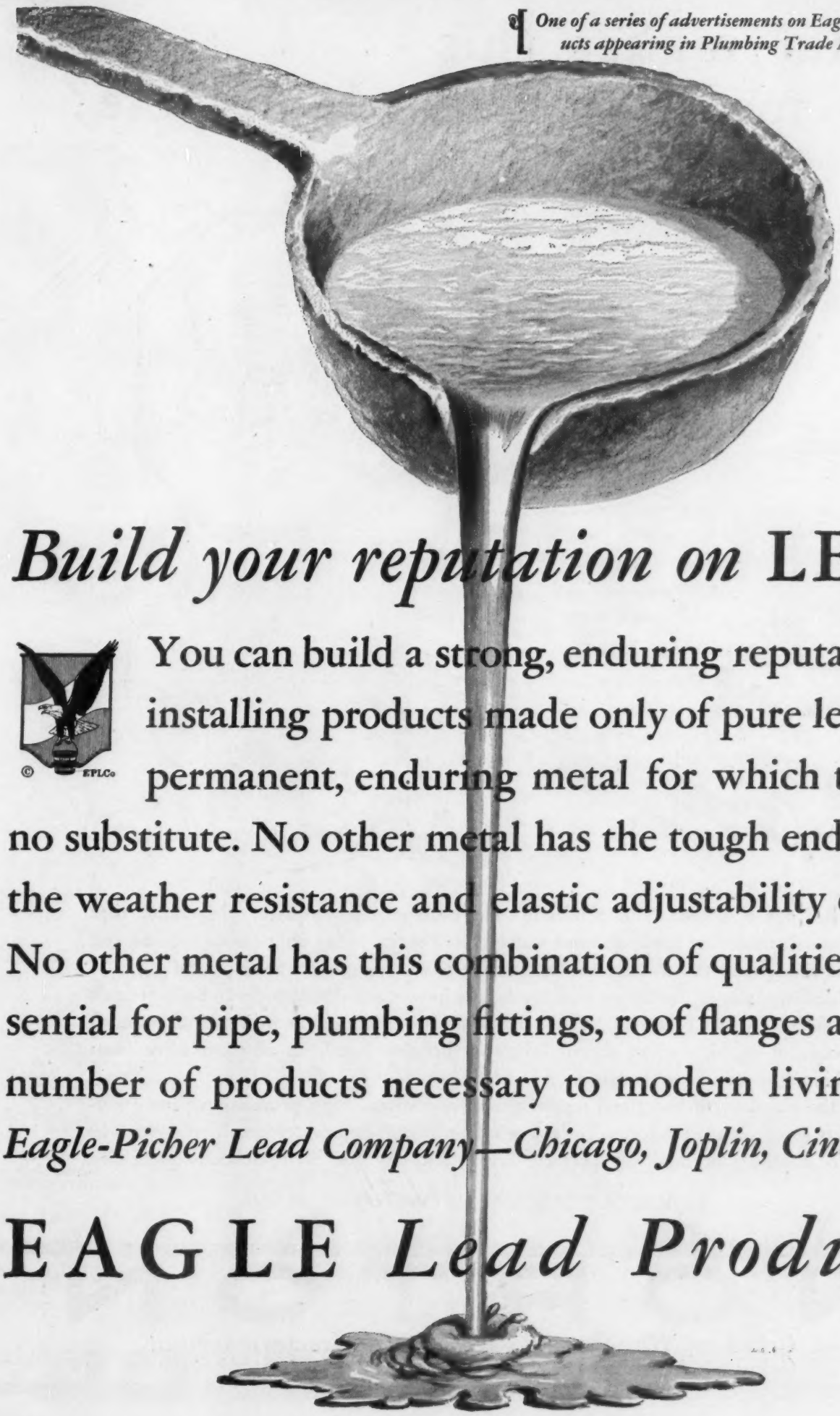
One of a series of advertisements on Eagle Lead products appearing in Plumbing Trade Magazines



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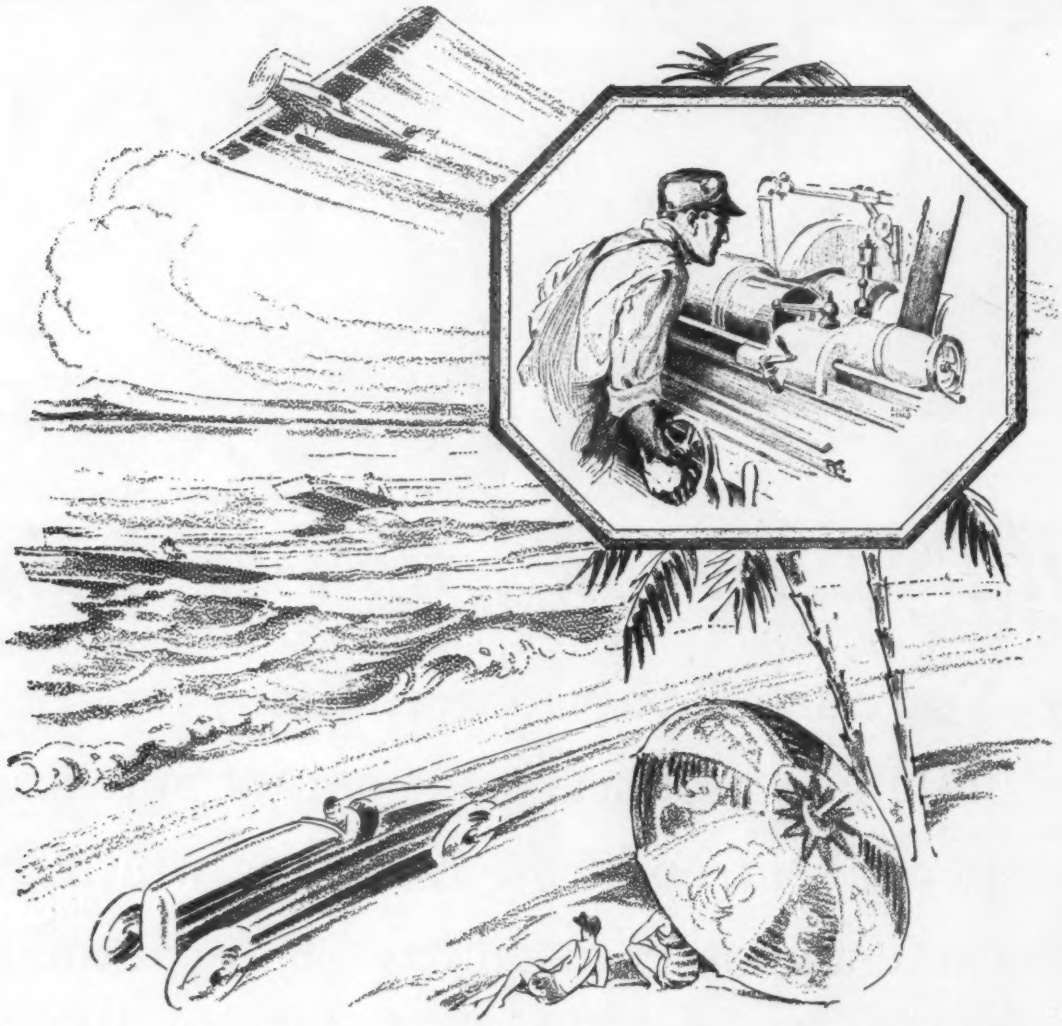

In this age of speed, "mile a minute" has beçome commonplace. Machines that reduce distances by land, air, and water travel excite today only casual interest and little thought of the mechanism that makes this tremendous speed possible.

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In the old days of hand and semi-machine operations, high production with accuracy was of course limited. Today, grinding machines produce precision parts, one after another, mechanically perfect, day in and day out, in tremendous quantities.

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"The Huddle"

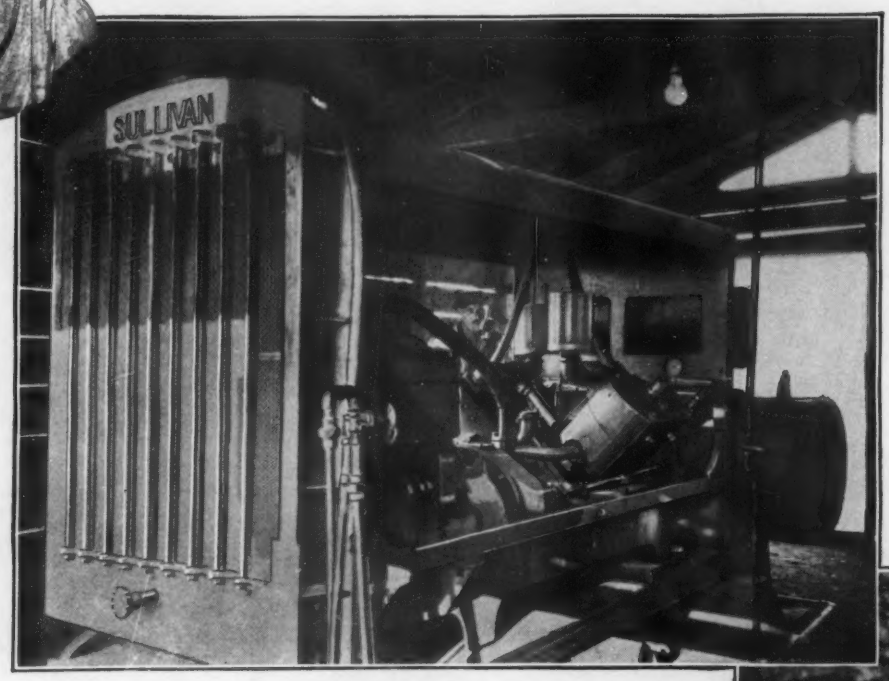
Signal: "Timken-Equipped" for Sure Gain

THERE is one way to get "the old college spirit" into everything mechanical which transmits power through moving parts —see that it is "Timken-Equipped".
For then friction is held in check, working parts are preserved to "FIGHT", "FIGHT", "FIGHT" wear with Timken tapered construction, Timken *POSITIVELY ALIGNED ROLLS* and Timken electric steel. This is worth remembering in buying or designing motor cars and all other machinery.

THE TIMKEN ROLLER BEARING COMPANY, CANTON, OHIO

TIMKEN *Tapered Roller* **BEARINGS**

Hadrian in 128 A. D. had only Slaves to build the Athens Aqueduct



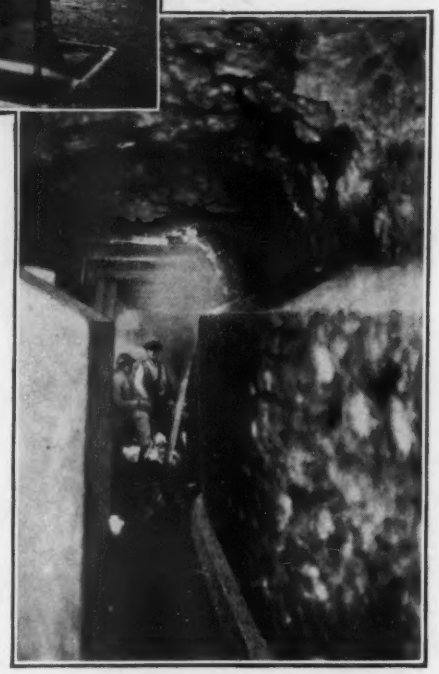
At Left:

One of the Sullivan Vibrationless Portable Compressors which supplied air power to repair the old aqueduct.

TheseCompressors are "WK-314," 310-ft models on skids. (Price $3420.00 f. o. b. factory.)

Below:

Relining the ancient Hadrian Aqueduct, built in thesecond century.



Ulen and Company, in 1928, Use Vibrationless Compressors

Eighteen hundred years ago, the Roman Emperor Hadrian built an underground aqueduct for Hadrianopolis, his "New Town" at Athens — to bring water from the hills.

Great slave gangs toiled the fifteen miles with crude tools and dangerous methods — burrowing like animals in the narrow galleries.

Today this aqueduct still carries water to Athens — a monument to ancient engineering.

But what a contrast was the cleaning and repairing done recently on this old waterway by Ulen and Company of New York—with electricity, dynamite, and air power!

How different from the slow, uncertain slave labor, was the positive, tireless action of Sullivan Vibrationless Portable Compressors — which ran constantly, 24 hours a day, 30 days a month, to supply compressed air for the work!

Vibrationless operation and consequent dependability have made Sullivan "Vibrationless" Portable Air Compressors famous all over the world — for construction and mining work.

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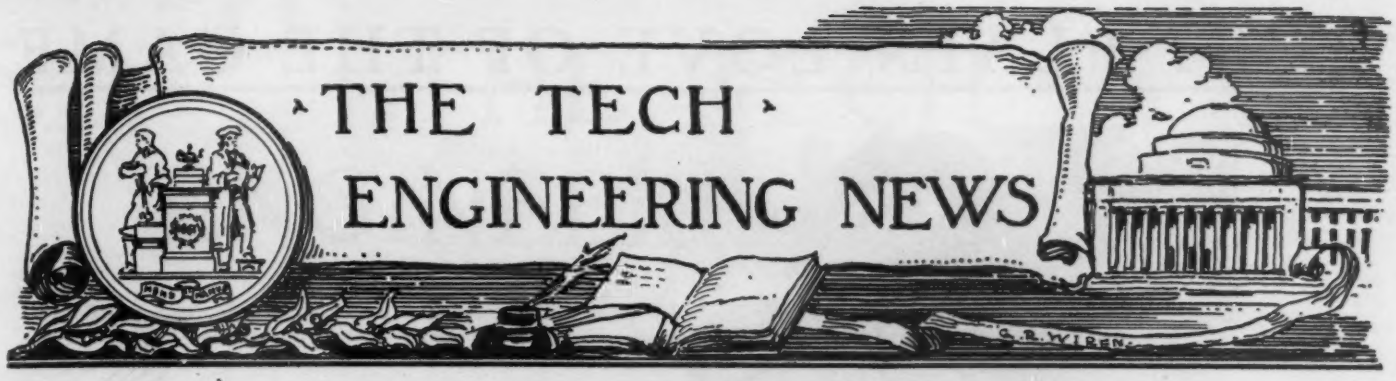

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JUST PLAIN LOVE OF THE GAME

TWENTY-FIVE THOUSAND STONE & WEBSTER MEN KNOW THAT THE GROWTH OF A PUBLIC UTILITY COMPANY DEPENDS ON ITS SUCCESS IN SERVING THE PUBLIC.

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—*A Manager's Report*

Stone & Webster men are recognized for the part they play not only on the job but in the community. Wherever there is a Stone & Webster company, there you'll find a group of men, bound together by a common fellowship, taking an active part in local affairs; working for civic betterment, helping to develop local industries. The Stone & Webster training fits its men for public service.

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THE TECH ENGINEERING NEWS

THE PROFESSIONAL JOURNAL OF THE UNDERGRADUATES OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

VOLUME IX — NOVEMBER, 1928 — NUMBER 6

The Holland Tunnel

A discussion of the power distribution and traffic control of the greatest underground thoroughfare

By J. P. MAXWELL
Switchboard Engineer, Westinghouse Electric and Manufacturing Co.

A GREAT work, in its extent unprecedented, was brought to completion early in November, 1927 with the opening of the vehicular tunnel between New York and New Jersey. The tunnel perpetuates the memory of Clifford M. Holland, whose name is carved over the stone portals of the two tubes. It was he who directed and animated the work of construction.

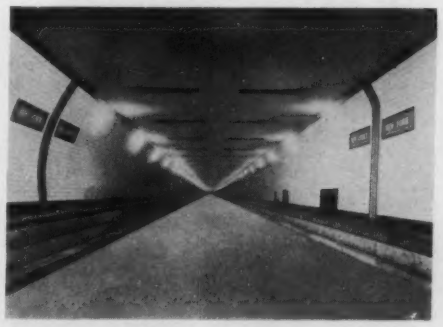
These tubes were built to relieve the congestion of traffic over the North River ferries, and to aid in the movement of goods between the two states. The opening of the tunnel has made it possible to go from Manhattan to Jersey City in a few minutes, thus eliminating the inconvenience of waiting to board the ferries.

The Tunnel consists of twin tubes, one for east bound traffic and the other for west bound traffic. Each tube is circular in shape, having an external diameter of 29 feet, 6 inches, and a total length of 9,250 feet. Inside each tube a twenty-foot roadway is built, and on one side of each tube is a raised sidewalk primarily for the use of the traffic police. The alignment of the tunnel is by no means straight, having many bends and curves, particularly near the portals. The roadbed slopes from the entrance downward to the middle of the river and from this point upward to the exit.

Electric Power Supply

Although one feeder from a nearby generating plant would be sufficient to carry the load of all electrical equipment connected with the Tunnel, the engineers in designing the power layout, in order to insure continuity of service, arranged to have six feeders, three from a New York Power Company and three from a New Jersey Power Company, to handle this load. Two of the three feeders on each side of the river come from separate generating plants, therefore four plants would have to be totally destroyed before the power supply would fail.

Each feeder comprises a 13,200 volt, 3-phase, 60-cycle supply circuit. The three feeders from the New York generating plants enter at the New York Land Ventilating Building, and the three from New Jersey generating plants enter at the New Jersey Land Ventilation Building. In the land buildings each feeder connects to a three-winding, air-blast power transformer where the voltage is transformed to 2,300 and 440 volts. Through the tie bus any one of the incoming feeders can supply the complete tunnel. For instance, when one New York feeder is required to carry the load for the whole tunnel, the New Jersey power supply is fed through the 2,300-volt winding of the power transformer connected with the live feeder. Due to both electrical and mechanical interlocks no single incoming feeder can be paralleled with any other, whether it originates from New York or New Jersey.



A STUDY IN PERSPECTIVE
A view of Holland Tunnel interior. Note State line in foreground

All oil circuit breakers are of the truck type design. The tie breakers for the 13,000-volt incoming line and the 2,300-volt motor breakers are of standard design. The 440-volt motor breakers, however, are built in two tiers in order to save space. The design of these truck breakers provides for withdrawing them onto a special truck shown in Figure 1.

The ventilating buildings contain not only the fans, ducts and stacks, but also the switchboard control of the feeders and motors. In other words, they are the substations for the electrical power supply. These substations provide for controlling the fans either from a central switchboard or from a switch box located near the motor.

Switchboard and Local Control

The switchboard is located on the top floor of the ventilation building. These boards are composed of a number of steel cabinets, each cabinet being a special design made by the Westinghouse Electric and Manufacturing Company. Each cabinet is built of one-eighth-inch "stretcher-level" steel. The rear of the cabinet has a swinging door which makes it possible to gain entrance to the interior of the cabinet for wiring and mounting of material.

The switchboards for both the New York and New Jersey land buildings are identical and are composed of nine separate steel cabinets, as shown in Figure 2; whereas in the two river buildings the boards are similar except

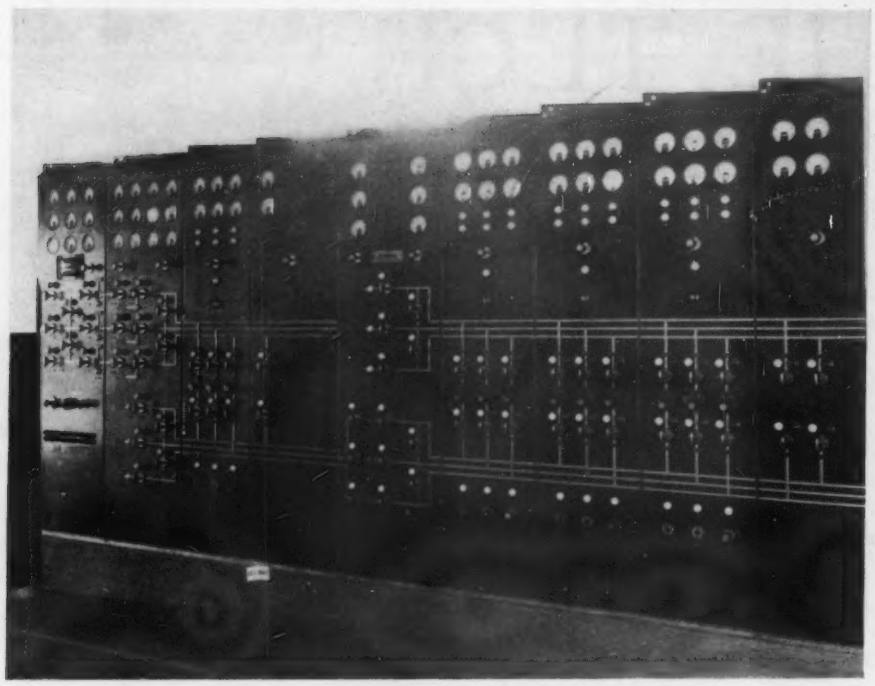


FIG. 2
The tunnel's power supply enters through these switchboards, located in the land buildings at either end of the tunnel

that here the sections for controlling the incoming feeder are omitted.

On the extreme left-hand end of Figure 2 is shown the control switches, indicating lamps and ammeters used in conjunction with the incoming lines. The miniature bus gives a single line diagram of the feeders and shows where the control switches are placed. Also it gives the location of the oil circuit breakers in the feeders. Each control switch has above it a green and a white indicating lamp. When the green lamp is illuminated, the breaker is in the closed position. The white lamp has two degrees of brilliancy, the dim light indicating that the breaker has been tripped manually, and the bright light indicating that the breaker has been tripped automatically, due to some fault or failure. A white lamp, located in the miniature bus for each feeder, when illuminated, indicates that there is potential on that particular feeder.

In addition to the switchboard control in the ventilation buildings, the motors, either 2,300 or 440 volt, can be controlled from another point known as local.

Referring to the illustration of the control board, the two white indicating lamps located above the control switches and below the ammeters are used to show the cycle of operation of the set. The upper lamp when illuminated indicates the blower motor is running and the lower lamp indicates that the exhaust motor is running. These lamps have two degrees of brilliancy; the bright light designates that the motor is running, but not up to speed. As soon as the light becomes dim, it indicates that the motor is up to speed and that the dampers in the respective ducts (blower and exhaust) are open. The ducts have dampers which are closed to prevent back feed of air when the fans are idle.

The key-operated transfer switch, located between the two control switches for each set, is used to lock out the switchboard control when the local control is being used. When this switch is in the "off" position, the key to the lock can be removed. The switch cannot be turned until the key is inserted and turned to unlock the switch.

If the operator wishes to control the fan from its local position, the key is removed from the transfer switch. By going to a cast-iron box, located on a column near the respective motor, the operator, by inserting the key in a similar switch, can perform the same control as was done on the switchboard. The only difference in the local control over the switchboard being that only one breaker can be controlled from the box. The New York bus is used to operate the blower motor and the New Jersey bus is used to operate the exhaust. In addition to the key transfer switch and the breaker control switch with its indicating lamps, there are located in the local box the same type of speed switches as was on the control board, also an emergency trip button and a damper cutout switch. All of this equipment allows one to perform a test on the motor and fan.

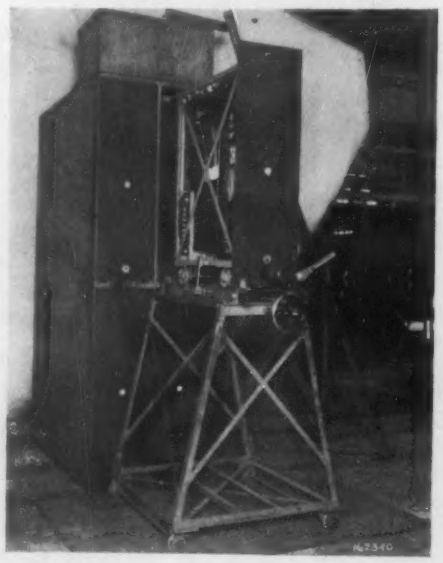


FIG. 1
The 440-volt motor breakers, shown above, are built in two tiers to save space. They may be removed onto truck as shown.

The same key used with the transfer switches unlocks the speed equipment cabinet and the primary disconnecting switches to the motors. Each set of motors has a different key, so that the interlocking feature is not jeopardized.

Safety on this enterprise has not been limited to the tunnel proper, but also to the control equipment. The key, as explained above, prevents more than one person from operating the control equipment, even though there are several control points. Another safety feature is the emergency trip button in the local control boxes. During the test period should something go wrong or should someone be in danger while working around the fan or motor, operating the emergency trip button will de-energize all circuits.

Whether switchboard or local control is employed, the protective features for the motors are the same. Each motor circuit has a thermal overload relay with a short circuit element. Besides protecting the motor from excessive temperature rise, due to overload, the short circuit element will act instantaneously if a short occurs.

Supervisory Control

By means of transfer switches on the switchboards, in all the ventilation buildings, the control of all the feeders, transformers and motor circuits can be transferred to the supervisory control board. This board is under the control of one man.

The Westinghouse control board composed of seven steel cabinets is built in the shape of an arc. Referring to Figure 3, the board is a symbolic representation, both of the twin tubes and of the electrical circuits, including all feeders and motors. The board is divided by black vertical strips into five sections, representing the four ventilation buildings and the mid-river sump. The names of the buildings are designated by name plates shown near

the top of the board. The two large trough-like castings running horizontally, one near the top and the other near the bottom of the control board, correspond to the north and south tubes. The plateaus at the ends represent the plazas, and the arrowheads indicate the direction of traffic.

Every oil circuit breaker control switch, motor speed switch, pump control switch, and the respective indicating lamps used in the tunnel equipment is duplicated on this board. By means of single direct-wire connections, and by the use of polarized type of relays the various switches control all the apparatus. The lamps indicate all switching operations. The scheme of operation of this equipment is not at all like the standard supervisory

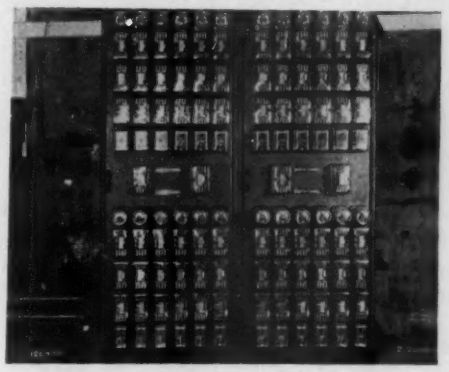


FIG. 4
Relays used in conjunction with the traffic-regulating signal equipment

control which makes use of the impulse method of automatic machine switching.

Referring to Figure 3, the large lamps located on the raised parts of the mimic tunnel, when illuminated, indicate what set of motors is feeding that particular section of the tunnel. The lamp on the upper raised section, above the trough, indicates that the motors are fed from the New York feeder, while the lamps on the lower raised section below the trough, indicate that the motors are fed from the New Jersey feeder.

The large indicating lamp located in the trough of the mimic tunnel is connected to the carbon monoxide recorder equipment. The illumination of this lamp indicates that there are in the exhaust ducts more than 3½ parts of carbon monoxide in 10,000 parts of air. The small red lamp located in line with the carbon monoxide lamp, when brightly illuminated, indicates from what point in the tunnel the fire alarm was sent. The lights along the edge of the troughs close to the raised section indicate what lighting cabinet is feeding the tunnel at that particular point.

The three switches, grouped together in a vertical center line above the three large indicating lamps on the mimic tunnel, are for speed control. Their features and operation are the same as the switches supplied on the control board in the ventilation building.

From the above description of the supervisory control system and its control board, it is seen that the operator knows and sees exactly how every piece of apparatus composing this gigantic network is performing. This animated map of the control equipment shows whether the incoming line breaker is still feeding the equipment, or whether it has been tripped out automatically; whether the designated fans are running properly at the selected speed; and whether the amount of poisonous gas in any section of the tunnel is dangerous. This map indicates whether or not a fire alarm has been sent in, and, if it has, in what section of the tunnel the fire has occurred. The bright and dim lamp scheme is used to indicate the level of the water in the various sump chambers.

In the same room as the supervisory control board, and to the right, stands the traffic signal board. The operation of this equipment, like the main control, can also be governed by one operator.

Traffic Signals

Four kinds of signals are used to direct the motorists through the tunnel — green light indicates that traffic lines are clear and to proceed; red indicates that traffic must stop; "Stop Engine" indicates all engines must be stopped at once; yellow light indicates that all traffic must proceed in the

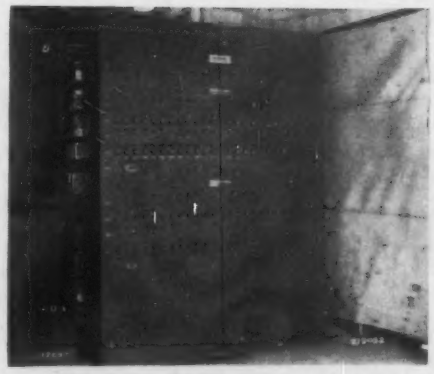


FIG. 5
This board gives the supervisor full control of the traffic signals in the tunnel, and indicates at all times how the signals are set.

right-hand lane only. The first three signals are mounted in a box, and are located on the left-hand wall of the tunnel near the ceiling.

These signal-light boxes are placed 240 feet apart, and at every other box, in the wall below, is the traffic officer's signal station. This station consists of the traffic light control buttons ("go" and "stop"), the fire alarm button and a telephone, all of which are mounted in boxes embedded in the tunnel wall, the boxes having glass doors.

Normally, only the green light will be illuminated, and the traffic allowed to move as fast as possible. Should a traffic jam occur within the tunnel, the officer nearest to the trouble will press the "stop" button and all traffic lights up to this point will show red, thereby stopping incoming traffic. The lights beyond this point will stay green, permitting the traffic ahead to proceed.

(*Continued on page 270*)

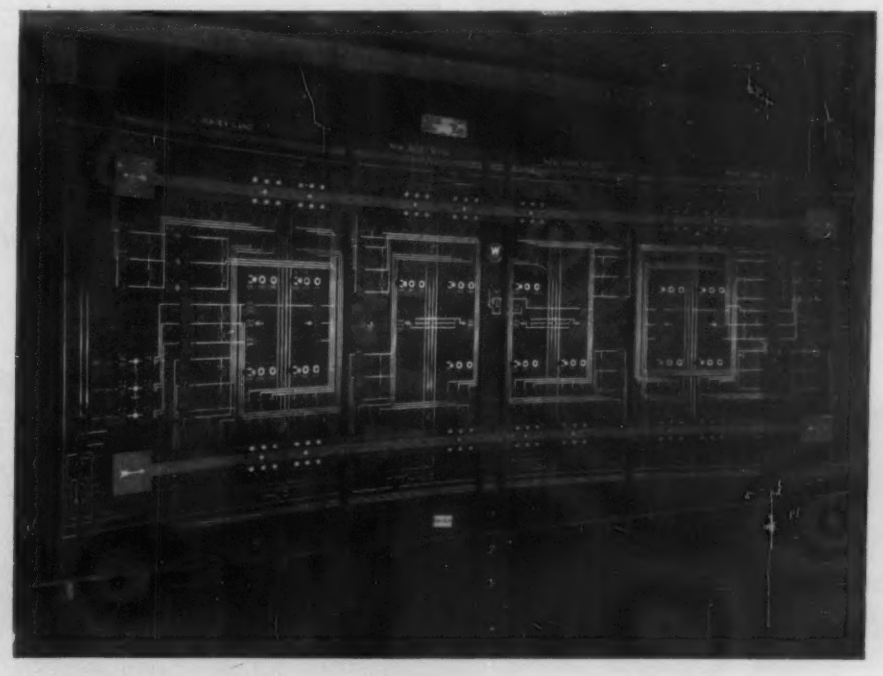


FIG. 3
The supervisory control board is a miniature of the tunnel tubes and of all electrical circuits connected with them. All the feeders, transformers, and motor circuits can be transferred to this board which is under control of one man.

Scandinavian Hydraulic Projects

An examination of the hydroelectric plants, hydraulic laboratories, and turbine manufacturers of Norway and Sweden

By JOHN B. DRISKO '27
Holder of Travelling Fellowship in Hydraulic Engineering

IN order to clarify this account, I shall write first of the water power plants visited; second, of the university laboratories; and lastly of the turbine manufacturers and their laboratories.

The first power plant visited was at Motala. This is a state-owned plant and was completed in 1922. It is situated at the outlet of Lake Vänern, which takes in nearly one fourth of the drainage area and provides wonderful regulation. Two 6000 h. p. horizontal twin Francis wheels in open pits drive 3-phase generators at 167 r. p. m. generating 50-cycle current at 6600 volts. This is stepped up to 70 k. v. for distribution. The power house and dam are built across the river which is about 165 feet wide here.

At present there are two units installed. Space is provided for three more, of which one will be a four-runner unit, so designed that it can be driven backwards by the generator to pump water into Lake Vänern from Lake Boren, which latter is the tailwater of the plant. Energy is to be taken nights and Sundays from other plants in the net. This pump-turbine unit will be used as a turbine only for load peaks, and so the runner will probably be designed for high pump efficiency rather than turbine efficiency.

A flood discharge allows water to flow under the power house, in a path similar to the water driving the turbines. The draft tubes are quarter turn, steel lined down to the middle of the turn.

The second plant visited was Untra. This plant belongs to the City of Stockholm. Four horizontal twin Francis units of 10,500 h. p. each drive 3-phase 6,800 volt generators at 125 r. p. m. Transmission is at 100 k. v. Space is provided for one more unit. The head is 40 feet, of which 7 are suction. The full load flow is 2,820 sec. feet per unit. The wheels are in open pits, and the draft tubes are quarter turn, steel lined down around the bend.

The turbine shaft bearings are outside the runners, giving an unsupported length of 38 feet.

John B. Drisko is a recent graduate of the Institute, having taken his degree of Bachelor of Science within the memory of a good many undergraduates now here. Upon his graduation he received a traveling fellowship in Hydraulic Engineering, and has since been studying in Germany. This article is an account of a trip through Norway and Sweden and his investigation of engineering problems in those countries.

This article should be of interest to every student not only because of the knowledge of foreign projects imported to him, but also because Mr. Drisko's work is typical of the work of the young Tech graduate. Little is known of the progress of the engineer immediately after he has left the Institute. Here, however, is set down the actual experiences of a Tech graduate. Perhaps it will dispel the mystery of what a young man does after Tech has done all it can for him.

Three small horizontal spiral case wheels of 112 h. p. each, running at 400 r. p. m. provide excitation current at 440–600 volts. These wheels had a suction head of 12 feet.

At this plant, as at every Swedish plant, the ice problem in winter is serious. At Untra there were 11 different booms to keep off the ice. A special chute skims off any ice that comes to the forebay. As at every Swedish plant, there was a chute for passing logs. High water is discharged at either of two sets of lift gates situated away from the plant.

A few miles below Untra is a plant, Alvkarleby, belonging to the State. This plant, complete in 1915, has five double twin horizontal Francis turbines — *i.e.*, four runners on one shaft. The fall varies from 54 to 65 feet. The turbines deliver up to 15,000 h. p. per unit, at 150 r. p. m.

Between Untra and Alvkarleby, at Lanforsen, there is a third plant under construction. The river flows in three channels at this point. The plant will be built in one of these; a second will be dammed with a set of gates and the third will not be dammed until later. The steepness of the river makes it possible to leave one channel open and not loose too much water.

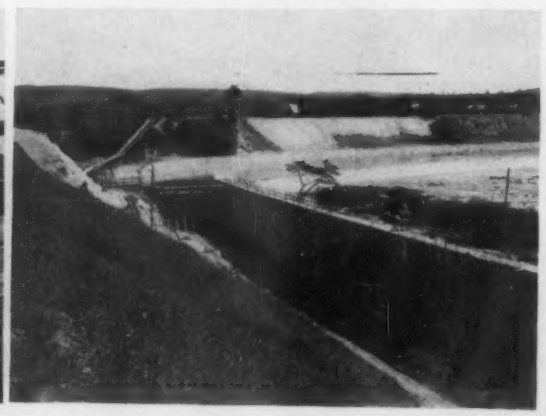
The power house will contain four vertical Kaplan units, taking as high as 4,240 sec. feet apiece, at 30 feet head. The turbines are rated at 13,000 h. p. and will run at 94 r. p. m. Very little dam construction is necessary and this will be of stone and earth. At Lanforsen the floor and the inner side of the bend will be faced with heavy timbers, instead of steel or hard-burned brick. The latter is quite commonly used in Sweden. All concrete at Lanforsen contains trass, which renders the concrete watertight. The mix used for much of their work was cement .8, trass .2, sand 2.4, broken stone 2.9. The total cost of the plant will be about 14 million crowns ($1=3.7 kr.). Turbines will cost one million and flowage rights about two million.

About 300 men were working on the job in two shifts. The long period of daylight in summer in Sweden enabled them to work from 5 a.m. to 10 p.m.

All the derricks and cranes and other equipment used on construction were electrically driven.

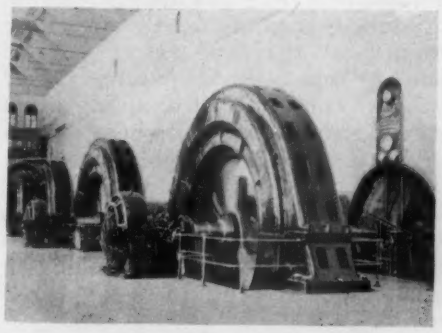
At Falun I talked with the water power engineer of Stora Kopparbergs Mining Co. He told me of a very interesting problem they have there, and their solution of it. They own three water power plants which

HAMMARFORSEN
Sector gate at the right, and two sections of needle dam at the left



MUNKFORS
View of power canal, looking upstream

supply power to their works. The largest part of the load is non-rotating such as electric furnaces. This means that there is little stored energy in the system, and the voltage and the frequency are subject to severe fluctuations. In order to get around this difficulty they are going to install a flywheel and two motors. The existing equipment has a kinetic energy of rotation of about 8.7 million kg. meters. They considered putting weights on some of the generator rotors, but this would yield but 2.7 million kg. m. for an outlay of 120,000 crowns. The system they adopted will give about 20 million kg. m., at an expense of



UNTRA
The generators at the Untra station

100,000 crowns. The flywheel will be in three parts and the diameter is 2.3 m. or 7.5 feet. The wheel runs in a vacuum to avoid air friction, and at 3,000 r.p.m. It will weigh about 15 tons. There will be no axle hole through the parts of the flywheel, as that would weaken the wheel too much. Instead, 8 small holes will be used to bolt the wheels together and to the shafts. The wheels will be tested at a speed of 4,000 r. p. m. This testing will stress the material beyond the yield point, so that the material will have an initial negative stress. The flywheel will be installed between a synchronous and an induction motor which are floating in the system, and will tend to keep these at constant speed and hinder any variations in voltage or frequency in the whole system.

The next two plants visited were of the Stora Kopparbergs system. Forshuvudforsen has two vertical Francis units of 7,700 h. p., under a head of 34 feet and a speed of 83.3 r. p. m. The dam has four large roller gates to control the spill. A third propeller turbine is being installed. The original plant is described in *Engineering* in January and February, 1925.

Bullersforsen, with six units, has a capacity of 20,000 kw. These units are double twin Francis wheels running at 180 r. p. m. and generating 60 cycle 3-phase current at 7,000 volts. Four of the wheels have been rewound to run at 150 r. p. m. and generate 50 cycle current at 1,900 volts, which is then stepped up. While I was at the plant, two of the rewound generators were running at 180 r. p. m., supplying 60 cycle current, and two at 150 r. p. m. The head here is 39 feet, and the normal water quantity for each turbine is 1,230 sec. feet.

From these plants I went north to the new plant at Hammarforsen. This plant has two vertical Francis wheels running at 94 r. p. m. The head is 62 feet and Q is 2,650 sec. feet per unit, giving 13,000 h. p. for each set. The suction head was from 16 to 19 feet.

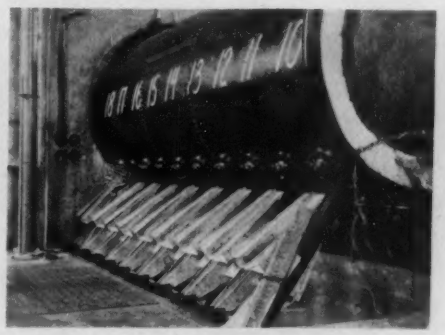
The draft tubes were of the quarter turn type and elliptical in cross section. The maximum dimensions of this ellipse were 36 feet horizontally and 23 feet vertically. The tubes are lined with hard-burned brick. This provides a good surface but is slow and expensive to build in.

The generators are supported on concrete cones which decrease from generator diameter to turbine diameter. These cones are about two feet thick. Space has been left between the power house and the river bank for the erection of three more units. Foundations for the bracing which the cofferdams for the extension will require, were placed at the same time as the other foundations.

The dam, which runs out from the power house, has a sector gate 115 feet long, and two sections of needle dam with a total length of 195 feet. The piers along this dam have steel plate around the upstream face, as protection against ice and logs and floating matter.

Two old plants near Trondhjem, Norway, which were visited, had twin horizontal Francis wheels set in in a short section of horizontal pipe. The water was brought into this pipe by a penstock which entered perpendicularly to the axis of the pipe, and at a point midway between the runners.

The plant at Bofors is a recently completed vertical Kaplan unit of 2,300 h. p. with a head of 23 feet. The intake gate is arched away from the pressure so that the ribs are in compression. Sealing is done by rubber strips which slide tighter and tighter against tapering faces as the gate drops. The by-pass at the plant is automatically controlled so as not to starve the plant below, in case of low demand on this plant.



TRONDHJEM
Outfit for calibrating weirs

The new station at Munkfors is to contain two Kaplan turbines of 15,000 h. p. each, at a head of 15.4 meters, or 51 feet. A series of falls and rapids and a low dam for an existing plant make any new dam construction unnecessary. A long canal, largely in rock, has been excavated and is being faced. The greater part of this canal has vertical walls which are of stone masonry. At the upper end a long section of one wall serves as a side spillway. The power house is largely in rock. The draft tubes were being prepared for concreting at the time of my visit. The draft tubes are of the Kaplan type and are lined with steel plate welded into pieces that could be handled and shipped and then riveted together. The draft tubes are not parallel — they toe in so that the outflow faces are at an angle with the axis of the tube.

ROTTNEROS
Reinforced concrete log shute for the pulp mill at Rottneros

Another small Kaplan wheel is now being put in at a pulp mill in Rottneros. The wheel is already installed and is of 1,500 h. p. The head varies from 26 to 33 feet. Q is from 490 to 525 sec. feet.

The last two stations visited were Trollhättan and Lilla Edet. These are both state-owned plants.

The former has a fall of 105 feet. An intake canal over four-fifths of a mile long — in reality two canals for the greater part of the length — which is cut to a large extent through solid rock leads to the forebay. The canal is too small: the sides are left rough which causes much dead water and swirling, and the velocity is very great. The forebay has an ice-chute to skim off any ice that gets to the forebay.

(*Continued on page 260*)

Modern Marine Power Plants

"Fulton's Folly" grown to be the pride of modern engineering

By R. C. M. Calvert, Jr. '32

As the romantic old sailing ships of the past were forced to give way to noisy, dirty steamers, so did those first steamers, driven by reciprocating engines, yield to the more efficient turbine driven ships of yesterday. Today, we find the turbine drive being superseded by turbo-electric, diesel, and diesel electric drive, each change marking a step forward in economy, maneuverability, and general efficiency.

The old double, triple, and quadruple compound reciprocating engines having a thermal efficiency of not more than 20 per cent were huge affairs which took up much of the valuable space between decks. They were noisy, dirty and unreliable; and their great weight and constant vibration necessitated the use of heavy bases. Particularly on passenger vessels were the vibration and noise an annoyance, and in every case strength of the hull was lessened as steel became crystallized, or as seams were started. Furthermore, automatic control of speed in rough weather was impossible. A speed-time curve on one of these engines in a rough sea looked like a mountain range; for each time the propeller lifted out of water for a few seconds the engine, shaft and propeller itself were subjected to the strain of greatly increased speed. As the screw was again covered with water the driving unit was suddenly decelerated to normal speed, causing an enormous momentary overload. Of course, many types of governors were tried but none delicate enough and fast enough was ever found. A governor strong enough to prevent overspeed would not drop quickly back to normal when the propeller reëntered the water, and a temporary underspeed resulted. This method, though safe, was not efficient; hence, engine parts, shafting, stuffing box and propeller had to be made strong enough and heavy enough to withstand the overload. This fact was one of the greatest deterrents to economy.

Not many years ago steam turbines reached such a state of development that their use in ship propulsion was tried. Here, after design had been more or less standardized, they proved very successful and in most cases economical. There were, however, a number of serious faults. The old question of how to secure quick automatic governing became even more important and was only partially solved. The new governors prevented dangerous overspeed but allowed the same drop below normal before disengaging or opening, and the speed-time curve was still rather hilly in rough weather. In fact, on large vessels, particularly naval vessels where a large crew was available, a special watch was stationed at the manual control to anticipate overspeed and return to normal. With a little practice an intelligent man could tell by the feel and sound of the propeller throb when it was lifting free of water and when returning; and by moving the throttle manually could maintain a constant speed. This method, however, was unreliable and far from ideal.

During the period of development of the steam turbine great strides were also made in boiler design. Higher pressure and greater superheat were made commercially possible as is shown in the *S.S. Dixie*, which runs at a pressure of 330 pounds per square inch at 200° Fahrenheit superheat. In her boilers oil is burned, about 0.75 pounds per horse power being used. In other ships, however, coal is fed by automatic stokers into furnaces having travelling grates; the amount of air is automatically controlled; and ashes are removed entirely by machinery. The flame and heated gases travel through a water-tube boiler, rather than the old fire-tube type, and then are often used to preheat the feed water. In still another type of boiler pulverized coal is blown through a jet or nozzle into a special shape of fire box where secondary air is added in the right proportion. The thermal efficiency of the boilers is high but the cost of pulverizing coal to the necessary fineness — about three hundred mesh — is almost prohibitive unless new and cheaper methods are found.

The *S.S. Mercer*, one of a number of similar cargo vessels equipped with Scotch boilers, was reëquipped for use of pulverized coal and made the first transatlantic voyage using it exclusively. The experiment, though not wholly successful, showed possibilities of this fuel, even in the Scotch boiler having a firebox only four feet in diameter. (It may be noted here that boilers especially designed for this type of fuel often allow a flame travel of thirty feet.) The greatest difficulty experienced was the sticking of partially burned coal to the walls of the boiler. This fault, however, can be obviated by even finer pulverization. Further work along this line is being done and great improvements are expected in the near future.

With the question of higher thermal efficiency partially solved, engineers turned their attention to some of the other problems. One of the greatest drawbacks of direct turbine drive is the fact that reversing can be accomplished only through gears or through use of a second set of turbines, neither of which methods is very satisfactory. The use of gears adds enormously to first cost, to upkeep, to weight, and to space occupied; while use of reversing turbines is even more expensive. This fact and the slowness of maneuvering led to the trial and successful design of so-called "electric gearing." Comparatively small high speed turbines of highest possible efficiency turn correspondingly high speed generators. These generators, usually synchronous, alternating current machines, furnish

(Continued on page 251)

We owe the photographs used in our pictorial section to the courtesy of the following: United States Shipping Board, The Winton Engine Company, the General Electric Company, Busch-Sulzer Brothers Diesel Engine Company, Westinghouse Electric and Manufacturing Company, the International Mercantile Marine Company, and the De Laval Steam Turbine Company.

Fig. 1. This marine type full diesel develops 200 h. p. at 700 r. p. m. and weighs only 37 pounds per horse power.

Fig. 2. Shows the latest type of light weight, high speed, marine engine weighing only 14.5 pounds per horse power.

Fig. 3. One of the first pictures of the "S. S. California," 601 feet long, 80 feet wide, and 32,450 tons displacement, the largest American built liner and the largest electrically driven commercial vessel afloat.

Fig. 4. Shows how much smaller and of how much more convenient shape are high speed diesels than those built for low speeds. Note also the cleanliness and lack of crowding of a modern engine room.

Fig. 5. Good view of a large engine room with 600 h. p. diesels, main generators, and auxiliary generators.

Fig. 6. A Westinghouse combination impulse and reaction turbine operating at 250 pounds per square inch steam pressure at 200 degrees superheat and exhausting into 28.5 inches of vacuum. This machine develops about 3,500 h. p. at 3,600 r. p. m.

Fig. 7. On the right is a 4,000 h. p. diesel designed for direct connection, and on the crane is a typical small diesel-generator set showing the prime mover, generator, and exciter all on a single base.

Fig. 8. Electric drive allows centralized control, but increases the number and cost of indicators and gauges. Notice the thirteen additional meters for each motor-generator set.

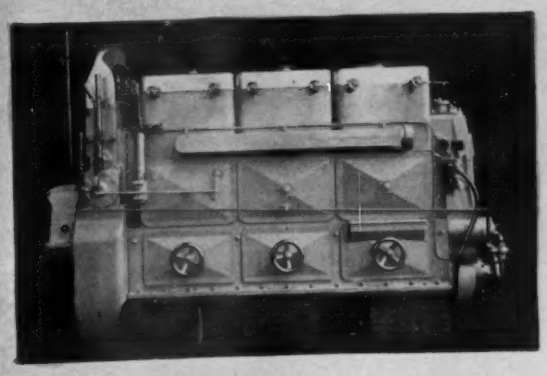
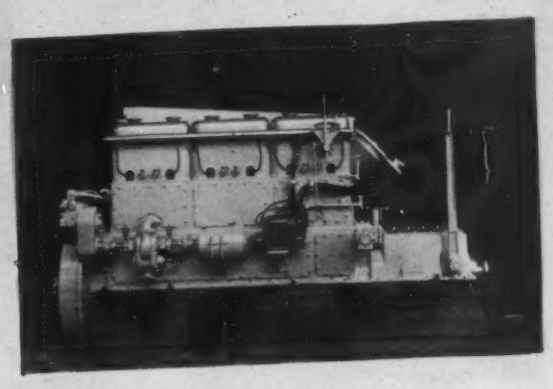


FIG. 1



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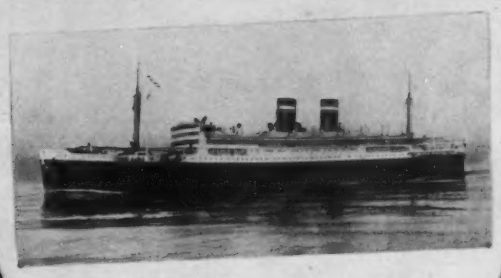
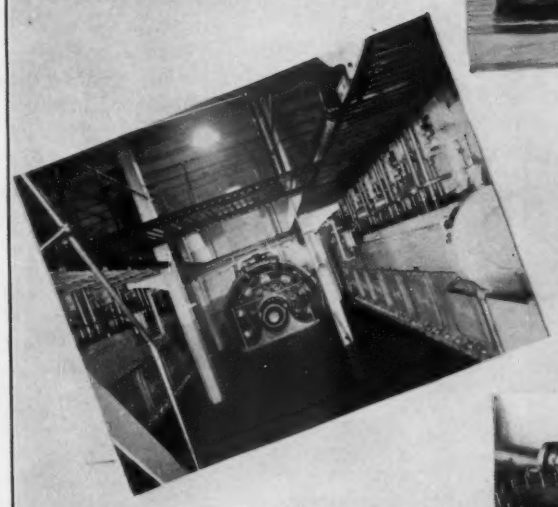


FIG. 3



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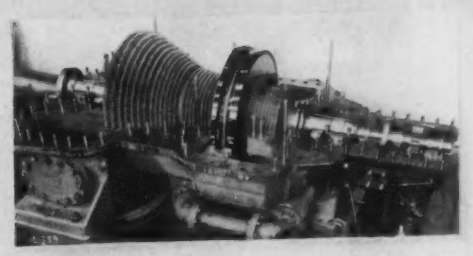

FIG. 6

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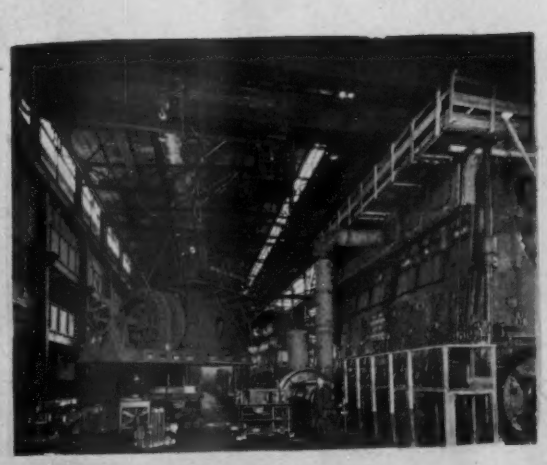

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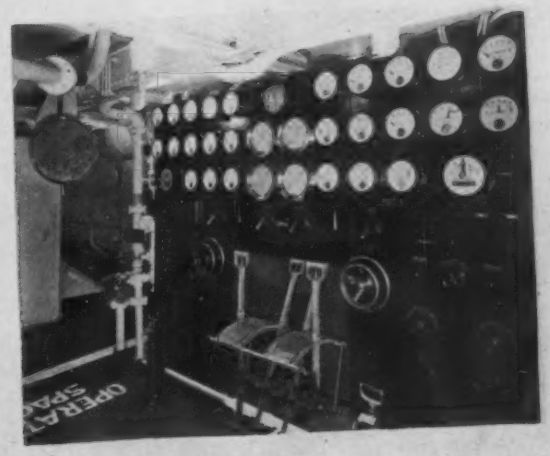

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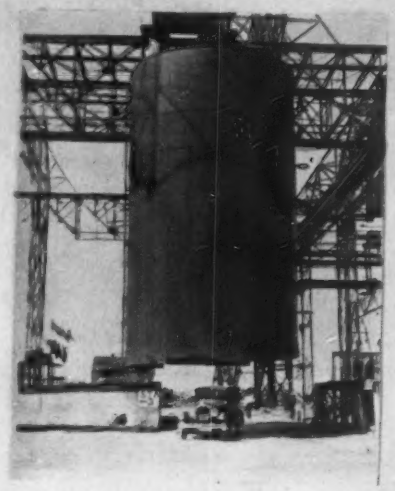
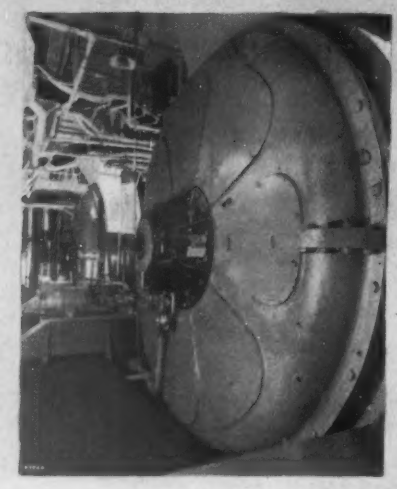


FIG. 9



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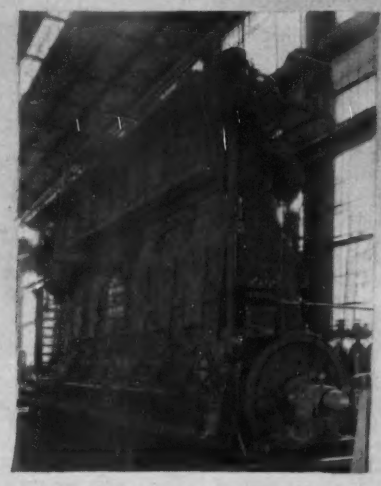

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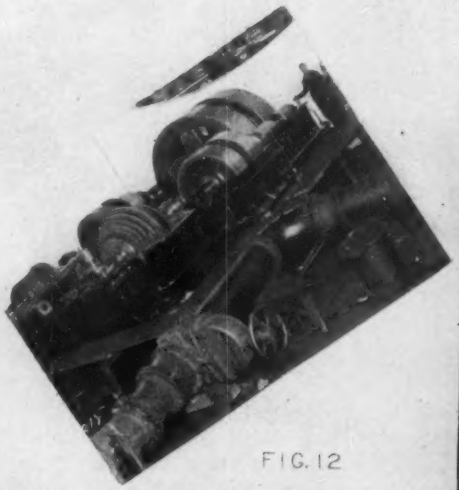


FIG. 12

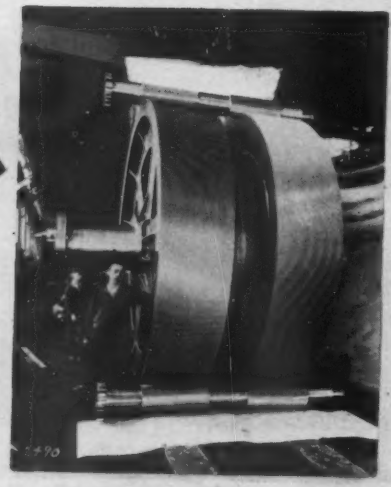


FIG. 14

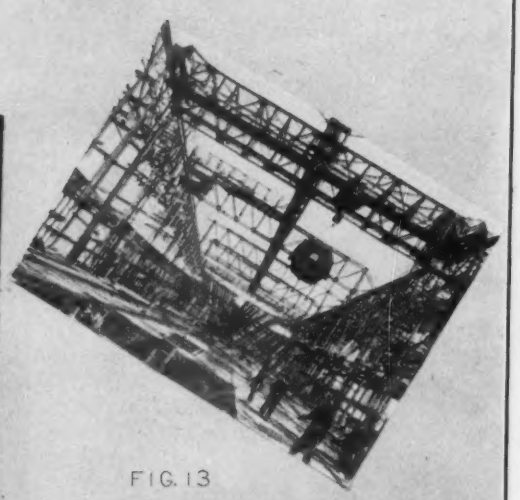


FIG. 13

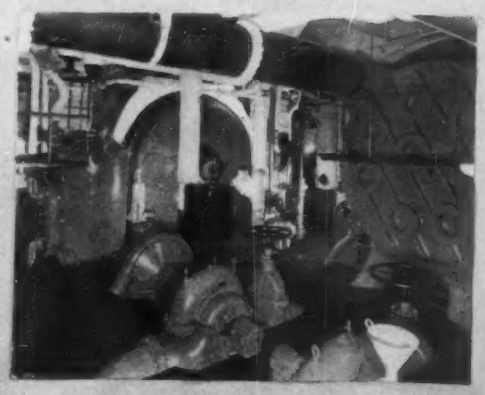


FIG. 15

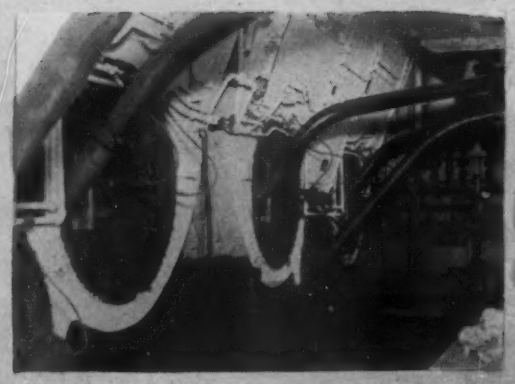


FIG. 16

Modern Marine Power Plants

(*Continued from page 248*)

current for the synchronous induction propulsion motors, and in many cases for all auxiliaries such as cargo winches, steering apparatus, blowers, stokers, and lights. Nevertheless, suitable small auxiliary sets are provided for use when the ship is not underway and in case of emergency. Control of propulsion motors is secured by change in speed of turbines with resulting change in frequency of alternating current. As the speed of a synchronous motor is dependent upon the ratio of the number of poles to the frequency of current, an even change in speed is obtained. For greater efficiency when cruising at reduced speeds for long periods, a simple switching arrangement for changing the number of poles in the field of the motor is provided.

Though some of the age-old faults are present in turbo-electric drive, the advantages are outstanding. High standby cost, the cost of maintaining steam for auxiliaries, maneuvering, and as a factor of safety, remain; but bridge control with consequent ease of maneuvering, almost instantaneous full power reversing, economy at slow speeds and smoothness of propeller speed curve more than offset the increase in first cost of equipment. By reversing leads to the motors almost instantaneous reversing of propeller rotation may be accomplished, a process which sometimes took as long as three minutes in direct turbine drive ships. This control, effected directly from the bridge by means of solenoid relays, makes maneuvering in crowded waters far safer and is more economical. In direct drive, cruising at reduced speed is costly due to the inefficiency of turbines at other than their designed speed. With electric drive a number of the generators may be run at full load to supply the driving motors a reduced amount of current. By the aforementioned changes in number of poles the efficiency of these motors may be made higher than that of the turbines at correspondingly reduced speeds. Furthermore, even though the entire load be lifted from a synchronous induction motor, its speed will not increase by more than 5 or 10 per cent, hence racing of the propeller in rough seas is eliminated.

All this experimentation and consequent standardization of design has been made possible largely through coöperation between the Navy Department and large shipbuilders. Such ships as the *U.S.S. Saratoga* and the *U.S.S. Lexington*, representing the highest power afloat, are electrically driven and are typical of the latest design. They are so much larger and have so much more power than similar ships in existence that their construction was considered by many engineers to be an enormously expensive experiment. This was to some extent true, but results have more than justified the attempt. At present, though small changes are still being made in turbines, they have attained 97 per cent of their estimated speed and only 85 per cent of their designed power. Altogether, the Department is so well satisfied with results thus far accomplished that they have planned to combine such construction in all sizes, as is proved by the fact that twenty-four scout cruisers and twelve coast guard cutters with electric drives are now in the process of construction.

For a number of years directly connected diesel engines have been used in marine propulsion. Varying success has been attained, and new designs are constantly appearing; but the general tendency is toward use of direct diesel power only in smaller ships or as auxiliaries. Fuel economy is better than that on steamers only in some instances, particularly where standby periods are long, as, for instance in the case of fire boats which must be ready for instant action at full speed. The diesel is easily reversible, hence its use on double ended ferry boats and on towboats is advantageous; but efficiency at reduced speeds is low, while bridge control is impossible or at least impractical. One of its greatest disadvantages is the enormous weight and height of the necessarily slow speed engines and the vibration caused by the correspondingly large pistons and crankshaft. Though huge direct connected units have been built and operated successfully, they are gradually giving way to the more flexible electric drive.

Diesel electric drive has come in for much deserved publicity in the past few years; on dredges, tugboats, ferries, tankers, cargo vessels, and yachts, its economy and convenience are pronounced. Because they are not directly connected the engines may be of the small high speed type, which are much more adaptable to available space, and which are comparatively free from vibration. Direct mechanical connection is made to direct current generators which are in turn connected by cables to the main propulsion motors, any excess power being fed to the auxiliary busses and used on blowers, hoists, and lights. Since the cables may be of any length, better arrangement and balancing of the units can be obtained without the drawbacks of long shaft alleys; and, furthermore, a multiplicity of connection between units of various sizes is possible, giving highest efficiency at all speeds. Propeller speed is controlled by use of rheostats in field circuits of driving motors; and reversal of rotation, accomplished by reversing the polarity of either field or armature, is even easier than with alternating current motors, providing a quick and certain way of stopping and reversing the ship. The fact that a shunt wound, direct current motor will not race when load is removed gives the same constancy of propeller speed as with alternating current, synchronous induction motors.

Bridge control is even more complete than with turbo-electric drive, and, once the diesel is started, all control is accomplished in the driving motor alone. This fact and the fact that standby cost is practically nothing make the system almost perfectly adapted to police boats, fireboats, and tugs. One of the greatest costs of maintaining steam propelled fireboats is that of keeping a full head of steam twenty-four hours a day. With diesel engines nothing has to be kept hot; full power in either direction is available at a moment's notice; and with "electric gearing" the maximum of maneuverability is obtainable.

Of the three modern marine power systems discussed here, the diesel electric drive is proving so far superior, that only a threat of great increase in cost of oil can prevent its becoming the most popular system of marine propulsion.

Fig. 9. One of the two huge stacks on the "S. S. California." The other, similar in every respect, is used for ventilation only.

Fig. 10. Shows a huge diesel engine designed for direct connection to propeller. This machine develops 3,000 h. p. at 90 r. p. m., and stands over 20 feet high.

Fig. 11. A close-up of the motor shown elsewhere hanging from crane.

Fig. 12. A 6,000 h. p., compound, double geared, propelling unit in the "S. S. el Oceano," giving a propeller speed of 80 r. p. m.

Fig. 13. In the better yards an elaborate system of carrier cranes and other machinery is used in the construction of large ships. Note how small the 6,750 h. p. motor looks, and compare the close-up of the same motor installed.

Fig. 14. One of the four two-pinion, double helical reduction gears in the "S. S. Mololo." These gears, having a ratio of approximately 12/1 and a pitch diameter of 140 inches, each transmit a maximum of 6,250 h. p. at a propeller speed of 120 r. p. m. and are the largest ever built in this country.

Fig. 15. Engine room of the "S. S. California," centrifugal water pumps in the foreground, port condenser at right, and starboard motor in background.

Fig. 16. Front view of furnace on "S. S. Mercer." The pipes in view carry powdered coal and primary air.

Emission Cathodes

A study of the materials used in cathode tubes together with the special methods of treating them

By MARY R. ANDREWS '06
Research Laboratories, General Electric

IT is an old story that when Thomas Edison was experimenting with the incandescent lamp, he observed what is known as the Edison effect. That is, he found that if he put an extra wire in his lamp, electricity would leak across the vacuum to this wire when it was connected to the positive end of the filament, but not when it was connected to the negative end. This constituted the first vacuum discharge tube. A little later, Preece and Fleming did considerable experimental work with this discharge. There existed for a number of years a theory that electron emission occurred only when chemical reaction took place, and it was not until Langmuir's and Richardson's work in very good vacuum that this theory was finally laid to rest. It has now been shown repeatedly that many metals give off electrons most efficiently only after they have been carefully freed from gas and when operated in the best obtainable vacuum.

The term "electron" was first suggested by Dr. G. Johnstone Stoney in 1891 as the name for the "natural unit of electricity," which indicates how recent is the development of electronics. Sir J. J. Thomson was one of the pioneers in the field of electronics, and O. W. Richardson carried the work far in the development of the theory of electron emission. It was the latter who suggested the term "thermionic" to describe emission obtained at or by means of high temperatures. Such emission is in most cases one of electrons, though with some gases and a few metals positive ions can be obtained as a direct result of their contact with an incandescent filament or surface.

Tungsten Filaments

The first successful tubes built to yield thermionic emission currents operated with filaments of pure materials. Fleming originally used carbon but this was later replaced by tungsten. Such materials are now, however, known to be poor emitters of electrons. That is, the heat of evaporation of electrons from, say, tungsten, is very high, and consequently the number of electrons per watt input into the thermionic source is low. However, such a filament has certain marked advantages. It can be heated to an extremely high temperature to free it from gas, and can be run for long periods at the temperatures of an incandescent lamp filament (2400° to 2500°). At these temperatures, electron emission is great enough to provide fairly large currents. Such pure metal filaments are now in use only in high power tubes where the anode voltage is high, and the types of emitters described below could not be used. At 2500° the emission from tungsten is over 250 milliamperes per square centimeter, or about four milliamperes per watt.

Thoriated Filaments

During his early investigations on this subject, Dr. Irving Langmuir observed that he was obtaining from certain filaments very much larger electron currents at a given temperature than he had from other pure tungsten filaments. Investigation showed that this high emission was due to traces of thorium oxide originally present in the tungsten. By further work, Dr. Langmuir developed the whole theory of the behavior of such filaments. Very briefly it is this: The thorium oxide is slightly reduced at high temperatures by tungsten so that a very small amount of metallic thorium is formed. This material can diffuse through the hot tungsten until it reaches the surface, but the attraction of tungsten and thorium for each other is great enough so that the atoms of thorium which would evaporate very rapidly from the surface of the metal itself, escape comparatively slowly from the surface of the tungsten. Hence a layer one atom deep of thorium is adsorbed on the tungsten surface. However, electrons escape very freely from thorium, and as a result we have a filament which has the strength and other mechanical characteristics of tungsten, but which is capable of giving off electrons as freely and even somewhat more freely than bulk thorium. The higher the temperature at which such a filament is run, the greater the electron emission, but also the more rapid the diffusion of thorium to the surface and its evaporation from the surface. The optimum temperature for operation, therefore, is the highest temperature at which the thorium surface can be maintained and still allow for a good life to the filament. This is found to be about 1950°–2000° K. At 2000° the emission from a thoriated surface is over two amperes per square centimeter or 80 m.a. per watt. At 2000° K. pure tungsten emits only about one milliampere per square centimeter or four hundredths of a milliampere per watt. Thus, the thoriated filament is some two thousand times as efficient as the pure tungsten at this temperature.

At the operating temperature, the thorium oxide in a thoriated filament is not appreciably reduced by tungsten, so the supply of thorium is obtained by running the filament for a few minutes at a much higher temperature (2800° to 2950° K.). The oxide reduced in this way is small in amount, but suffices to form and to maintain, for two thousand hours or more, the monatomic surface of thorium at 1950°–2000° K.

Carbonized Filaments

If, however, there could be put into the filament some material that would reduce the thoria very slowly at the operating temperature, a constant supply of thorium could be obtained. This is very desirable because if slight traces of gas are present in a tube, it becomes ionized by the electron current; the positive ions are drawn to the cathode, and there bombard the surface with sufficient force to destroy more or less rapidly the monatomic layer of thorium. A rich supply of thorium within the filament will, by diffusion, renew the surface so rapidly that the harmful effect of the gas will be overcome. Tungsten carbide has been found to be a material that reduces thoria slowly at incandescent temperatures. The carbide can be formed by running the filament at 2400° to 2600° in a low pressure of the vapor of some hydrocarbon, such as acetylene, naphthalene or illuminating

(*Continued on page 286*)

That a woman can earn her living in other ways beside teaching and nursing is an idea that the modern world has finally accepted. The business field has claimed the greatest number in the past; now women are gradually entering scientific fields. Tech offers its unequaled opportunities for higher scientific training to women as well as men. Although the number of the former has always been rather small, it has consisted of a high type of American womanhood, that has proved its worth to the world. Mary Andrews has become a valuable assistant in the General Electric Laboratories. This article illustrates the type of work she does, and indicates the type of work women may now do.

Editorials

WE WEAR OUR LAURELS

On the walls of the T. E. N. office hang the framed Certificates of Award which we have received in various competitions at past conventions of the Engineering College Magazines Associated.

The Engineering Magazines Associated was founded in 1921, with THE TECH ENGINEERING NEWS as one of its chief supporters. Its organization makes it possible to solicit national advertising for the entire group of twenty-two member magazines, and by uniform standards of practice and mutual coöperation, to improve the general character of undergraduate technical journalism.

Each year, a national convention is held in the fall, with one of the member magazines acting as host. At this convention, the various problems encountered in the editorial and business departments, in advertising and circulation, are discussed by delegates from the various publications.

This fall, the convention was held late in October at the University of Nebraska, and at that time, various awards were made for the past year in different lines of editorial activity. THE TECH ENGINEERING NEWS entered into four of these competitions for awards and placed among the first three in each of the contests. The best single editorial of the year was the one "Our Future," from the November, 1927 issue of THE TECH ENGINEERING NEWS. We also received second place for the best general editorials, and third for the best cover and illustrations.

We feel proud that the judges saw fit to honor us to this extent, yet at the same time we realize that we have set a high standard which we must constantly strive to maintain. To be a truly representative publication of the nation's greatest engineering school, and to carry her reputation unblemished wherever our readers may be, such must always be our goal — difficult of achievement — but worthy of our best endeavors.

A NEW COURSE

A major problem that faces all men who intend to enter the Institute is that of choosing the proper course of study.

A few have already solved the problem by the time of entrance and know quite definitely which course they intend to pursue.

However, the majority have not had the opportunities for obtaining this knowledge of themselves and their future work. Consequently they are doubtful as to the type of course which it is best for them to follow.

Since all the courses are practically the same during the first year, it is fortunate that no definite choice has to be made at the beginning of this time. If it is discovered by the end of the year that the wrong one has been chosen, the change to the proper one can be made without great difficulty or loss of time.

However, during the freshman year the student has little opportunity to go further into the solution of his problem. His immediate studies, which are new and difficult, claim most of his time and attention. There is little contact with the more advanced subjects in each course or with their practical phases as met after graduation. Practically the only help given to him in this respect is an hour lecture which, in the past, has been held each year by the combined departments. In this the subject matter and purpose of each course is outlined in a short talk by its head, but the brevity with which the matter is treated makes it of little value.

The result of this is that the student who was undecided at the beginning of his first year about the special branch of engineering for which he is best adapted, is not much better off at the beginning of the second year. If he is still in the wrong course any change which will come later must necessarily entail the sacrifice of much work and time.

Some means should be provided by which the student can be enabled at an early time to know more definitely which course he should properly pursue. It is suggested that this be accomplished by an additional course subject introduced in the freshman year. This should cover quite thoroughly the nature of the subjects taken up in the later years of each course, the opportunities to be expected after graduation, and the type of man required in each field. The topics could be presented in weekly lectures at which attendance would be required. The lectures should be delivered by authorities in each course, preferably the department heads.

Such a course would not impose an excessive additional burden on the students, for optional lecture subjects outside of the regular courses, similar to that in Atomic Structure, have proved to be very popular in the past and have been carried without trouble. Certainly the advantages to be derived from such a system of lectures would more than compensate for the extra time that the students would have to devote to them.

ENGINEERING AND FINANCE

A great deal has been said about the one-sidedness of the engineer, and many attempts have been made to inject a little culture into him while he was receiving his technical training. We would like to stress the point that there is another side the engineer needs to have developed that is not receiving as much attention as it deserves. In many respects it is far more important to him than any culture which he could acquire later on. We refer to a thoroughgoing knowledge of business and finance. Most technical students are required to take an elementary course in economics, but this is totally inadequate for any practical knowledge of financial questions.

The importance of finance in modern engineering cannot be overestimated. All large engineering companies today not only plan to carry through great engineering undertakings, but they also finance a large number of their projects. Stone & Webster, through its finance company, Stone, Webster & Blodgett, General Electric, through Electric Bond and Share, are two examples of the largest engineering companies carrying on an extraordinarily extensive program of financing engineering undertakings. Engineers' reports on large projects contain more and more the methods by which proposals are to be financed. If the engineer in a company of this modern type desires to rise to the top and occupy an administrative position, he must be equipped with an excellent knowledge of the business and economics of finance. It seems to us that the greatest opportunities for engineers today, outside of pure research, lie in the field of engineering finance.

ELECTIONS

The Managing Board of Volume IX of THE TECH ENGINEERING NEWS announces the resignation of B. King Couper '29 from the office of Managing Editor and his election to the position of Publicity Manager. Charles F. Edlund '30 has been elected to the office of Managing Editor from the position of Publication Manager.

THE COVER

"The End of the Day," in Gatun Lock, Panama, a lithograph by Joseph Pennell, is our cover picture this month. We are very pleased to be able to inaugurate our new cover design with another of the works of Pennell, who has done so much to portray engineering in art.

The men who swarmed out of the depths as the whistles denoted "the end of the day," inspired this picture. The long chain rising quickly and silently, far above the scurrying midgets, with a living design of men clinging to its end, provides a striking central motive.

The Engineering Field

Abstracts from the leading professional and trade journals

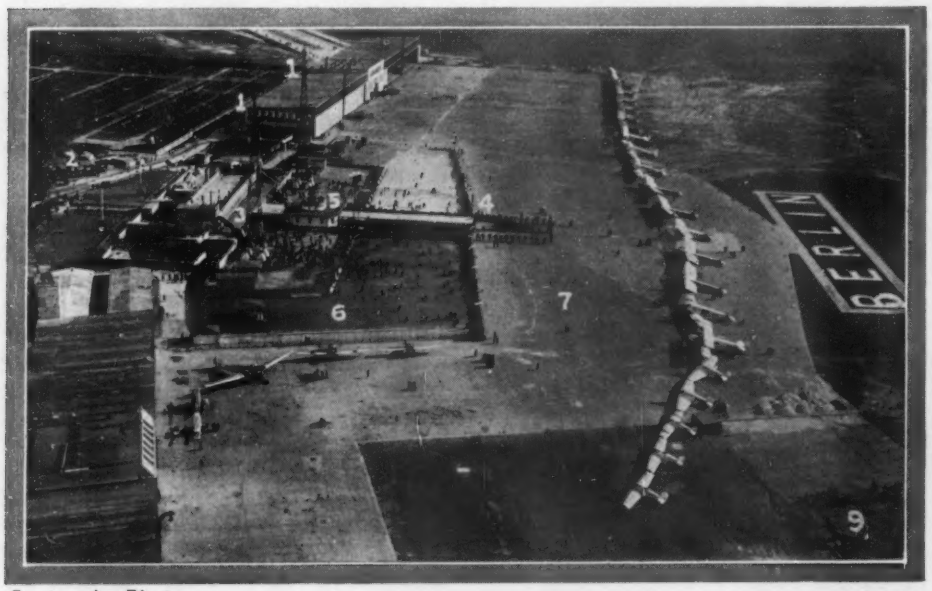
Cotton is an important part of the famous "Graf" zeppelin, which made an epic flight from Germany to Lakehurst, New Jersey, last month. Sixty thousand square yards of cotton were needed to make the outer covering and the thirty gas cells which support this new air liner.

The cotton used is a stout woven fabric made in strips 52 inches wide. The fabric of the envelope weighs three ounces per square yard, while that of the gas cells weighs only two ounces per square yard. Twenty thousand square yards of cotton fabric were needed to make the outer covering, which is specially treated with several coats of cellulose and some aluminum paint to reduce absorption of the sun's heat rays. The remaining forty thousand square yards of cotton fabric are needed to make the gas cells which are lined with gold-beater's skin to prevent the lifting gas from permeating.

The advantages of cotton fabric in making an airship are that cotton affords maximum strength with the lightest practicable weight, and that specially processed cotton fabric is strong enough to supply the needed protection with an exceptional light weight. In the building of an airship, the resistance to wear of cotton fabric is well illustrated by the dirigible "Los Angeles," which has successfully resisted all manner of storms for six years.

Tempelhof Air Field, located only a few minutes' drive from the heart of Berlin on the site of the former exercise grounds, is regarded as the most modern airport now in existence and is one of the latest evidences of European advancement in commercial aviation.

It is over two miles long and about a mile wide. Half of it has been settled by a garden city and the other half is used for the landing field and recreation grounds. The section used for the flying field is surrounded by a wire fence which is made visible by red and white colored shields, as well as a line of short shrubs. The general layout of the place is of such design as to make possible the most efficient and convenient operation.



Courtesy *Aero-Digest*

TEMPELHOF AIRPORT

1. Radio towers of wood. 2. Parking space. 3. Public observation roof on administration building. 4. Covered passageway to place where airplanes stop. 5. Special wind vane on tower. 6. Public enclosure. 7. Concrete surface. 8. Field drainage ditches.

The administration buildings and hangars are on the north side of the field next to the road which affords a convenient approach to the airport. The main building is a long brick structure with a large waiting room in the center. In this room, passengers are received, baggage is taken care of, and customs inspections carried out. In the two wings of the building are the administration rooms, a restaurant, and a postoffice which is equipped with pneumatic tubes for the transmission of mail to and from other postoffices. The airport also possesses a meteorological station which sends out, by radio, the daily weather report and other information which is essential for pilots. Many planes are now equipped with radio apparatus so that they may receive this information en route.

Great precautions are taken to prevent any accidents from happening that can possibly be avoided. A watchman is constantly on duty in the tower, and if a plane is sighted, sirens are sounded to clear the way and to stop any ships from taking off until the plane is safely landed. At night, the field is bordered by neon lights which have the power of penetrating a fog.

In the case of an accident, the port is equipped with many fire extinguishers, and a complete telephone system makes possible rapid communication between any part of the field and headquarters.

High Speed Motors are being successfully employed in the driving of street railway cars. The substitution for low speed motors appears easy, yet it is difficult because of the small space allowed on the trucks. The situation is taken care of by a single reduction high speed spur gear driving unit.

A unit of this type, built for simplicity and strength, is connected to the high speed motor with a flexible coupling to take care of wear and looseness in the journal box as well as the angularity of the axle. Having the motor keyed to the axle makes it possible to remove just the motor for inspection. The reduction gears are two in number, encased in an oil and dust tight housing, and are noiseless in operation. The reduction unit is mounted about the axle by means of a "swing link suspension" directly over the smaller gear.

Single reduction drive is claimed to be remarkably efficient in power transmission, since efficiency is lost at the rate of about three per cent for each set of gears used. With the quick acceleration of the high speed motor, noiseless gears running on ball-bearings in oil, and the simplicity of the reduction unit, a faster, stronger, quieter, and most efficient service can be had in street railway cars.

Rubber pads, as insulators of vibration, noise and abrasion of crossties, have been tried on a main-line railway in the Federal Malay States. Advance reports have been so favorable that equipment in this manner of an additional mile for further study has been authorized.

Pipe Coverings of combined asphalt and cement have been shown to possess many advantages. A new method for producing this double coat has been developed and consists of the following steps:

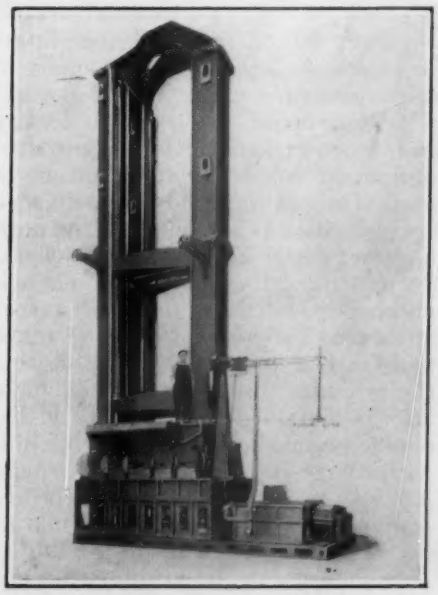
Minute particles of asphalt are mechanically suspended in water and this suspension applied to the pipe. When the water evaporates the drops run together producing a coating of asphalt. Dry Portland cement is then applied to the pipe directly over the wet surface of the asphalt, and acting as a blotter, takes the water up rapidly and sets, forming another layer. This cement is heavier than the asphalt and so sinks into it slightly, causing the two coatings to interlock.

This cement wrapping protects the asphalt coating from corrosive agents during its effective life and increases the surface density of the asphalt film considerably. The asphalt coating is also protected from stones and pebbles that may be in the earthfill. Transportation of the pipes is greatly simplified because they do not stick together as those coated with asphalt alone.

A pipe treated in the above manner can contract and expand in the ground without the coating being displaced or disturbed by the surrounding ground.

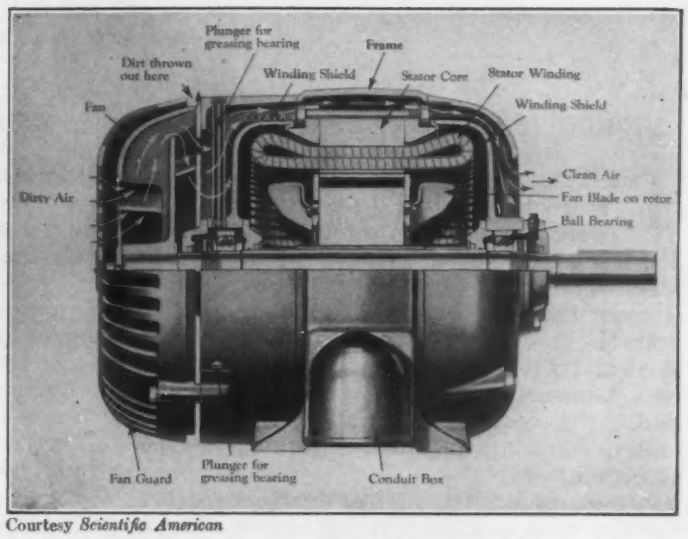
A Huge Testing Machine, to be used for the special purpose of testing the cables of the Hudson River bridge at New York City, has recently been constructed for the manufacturer who is to make the cables. It is the largest universal testing machine ever designed, standing over 40 feet high and weighing 275,000 pounds, and is capable of exerting a pull of 2,000,000 pounds.

Essentially, the machine consists of two upright members on a base containing the pulling machinery. Two heads, for transmitting the tension to the cable, are set between these uprights, of which the upper one is movable to three positions. It is fastened by means of large keys and must be handled by a crane when a change of position is to be made. Varying sample lengths may thus be tested up to a maximum of 25 feet. The lower head is actuated by three large screws which transmit the pulling power from a 75 h. p. motor in the base. Four pulling speeds are available. After a sample has been tested, the recoil is absorbed by a new design apparatus of the hydraulic type.



Courtesy *Engineering News-Record*

CABLE TESTING MACHINE



Courtesy *Scientific American*

CUT-AWAY OF NEW ENCLOSED MOTOR

Fully Enclosed Motors have been introduced by an eastern electric company in the line of induction two or three-phase alternating current motors. The motors are cooled by means of either internal or external fans, and are completely dust-proof.

In small riveted-frame motors a blower-type of fan is used. An internal fan transmits currents of air about the coil-head, which is the hottest part of the motor, transferring the internal heat to the coil-head coverings. A heavy current of air blown across the outside of the coil-head coverings carries the heat to the surrounding atmosphere and cools the stator. An external radial fan generates this current, and is so concealed inside of the outer shell of the motor that the appearance is that of a standard type.

In large skeleton-frame motors an exhaust-type of fan is used. One fan alone is used on this type of motor, and is mounted on an extension of the original shaft just outside of the front bearing. The external air current is pulled by the exhausting fan through openings located at middle of the back bearing, passing over the coil-head coverings and stator and escaping through the front brackets.

Fully enclosed, fan-cooled motors are of great value where they have to be exposed to a great deal of dirt, flying chips, dust, or moisture, for the coils can then be kept clean and free from short circuits. All of these types of motors have the same standard mountings and dimensions, except that the skeleton-frame motor calls for an extension of the shaft.

Flexible Concrete Forms were used in constructing all but the crowns of three domes on the Coolidge Multiple Dome Dam on the Gila River, Arizona. The demand for forms with constantly changing horizontal and vertical curves led to the design and successful use of a type of flexible panel, each of which was made of three 2 feet 8 inches by 4 feet wooden frames set side by side and faced as a single unit with 1-inch plank. These panels were practically as flexible as the 1-inch facing. When the overhang of the shell of the dome became more than 30°, the inside panels were secured by tie wires hitched to round-iron wishbone supports set in the previous pour. This method was found quite practicable and far cheaper at great heights than the usual network of struts and ties which was used only on the first hundred feet. Men in charge agreed that the use of this type of form was a large factor in the unusual speed with which the domes were completed.

Carboloy, a new metal of surpassing hardness, is a recent development of the General Electric Laboratories. It was presented for the first time at the latest convention of the American Society for Steel Treatment.

In composition, the new metal is an alloy of tungsten carbide and cobalt. Its property of hardness is greater than that of any other known material except the diamond.

Tools made of carboloy promise to be of great value in the future. One important use which has already been discovered is in connection with the cutting of materials containing metal inserts. Cutters made of cobalt-chromium alloy now used for this purpose must be resharpened after 150 cuts. Carboloy tools on the same work will be able to machine 11,000 parts before resharpening will be necessary, introducing a great saving.

Departmental Notes

MECHANICAL ENGINEERING DEPARTMENT

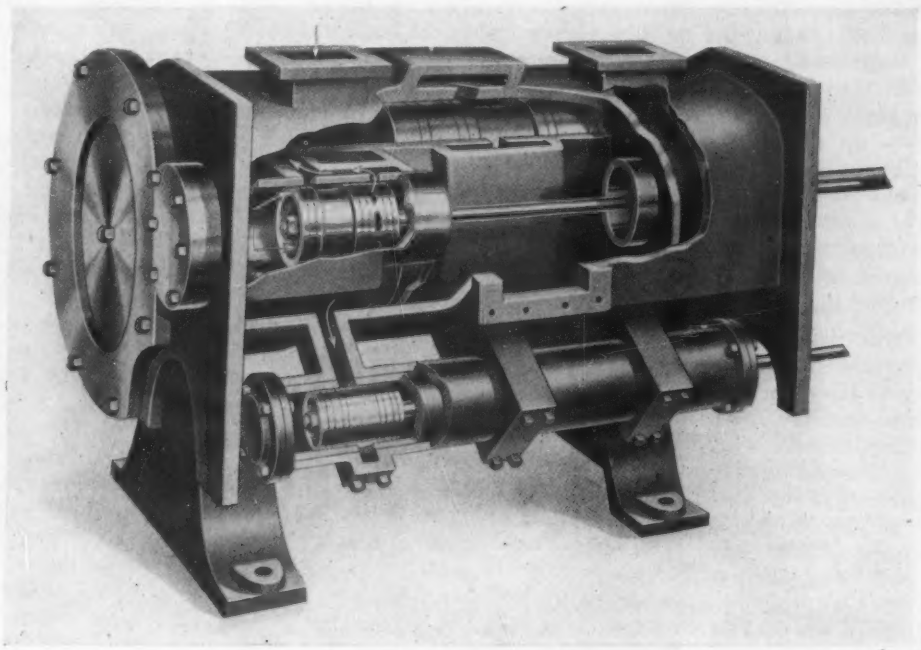
THE laboratories and the drawing rooms have during the past year worked with nearly a full schedule. While the number of students in the Mechanical Engineering Department is about the same as in the preceding year, the growth of other departments, particularly the Aeronautical and Business Administration, have, especially during the second term, kept the laboratories and drawing rooms working at capacity.

A new subject taught this year for the first time is a graduate course on the design of cotton machinery and of wool machinery. This work is given in connection with a special course leading to an advanced degree in textile engineering.

The textile laboratory has been equipped with additional optical apparatus for the study of fibres so that now one is able to make cross-sections and longitudinal views of any of the textile fibres with despatch and with precision.

In connection with the balloon tire, it has been found that unusual degrees of twist in the cotton cords making up the tire impart additional durability to the product. In order to study this question intelligently a new Fales and Jenks Twister has been installed in the textile laboratory. This is a special machine fitted for five different sizes of bobbins and for wet and dry twisting as well. With the large number of change gears accompanying this machine it is possible to twist a very wide variety of cords and cables in the study of the pneumatic tire. This is the first time that actual plying and cabling of yarn has been performed in our laboratory. The following additions may be noted in the textile laboratory as regards apparatus:

1. In connection with instruction in textiles about one hundred and fifty new lantern slides have been added, many of which relate to microscopic sections.
2. Interval Alarm Timer.
3. Three new Parks-Cramer high duty spray heads.
4. Carpet construction display case, Bigelow-Hartford Co.
5. Steady dial looper for finishing knit goods.
6. New abrasion machine.
7. Improved thickness gauge.
8. A twist counter.
9. Lowinson Micrometer for fabrics.
10. Full set of cork-covered rolls for spinning frame with display case.
11. New type, motor-driven, Mullen Bursting Tester (Perkins & Co., Holyoke).



A UNIFLOW STEAM ENGINE

One of this type has recently been added to the steam laboratory

To the equipment of the machine tool laboratory there has been added during the past year a power press, a high-speed metal-cutting machine, a recording scleroscope, an automatic balopticon, and a tool maker's microscope. Two belt-driven grinding machines have been changed over into motor-driven machines, making them practically the same as new machines, and a new light wave deflection bar has also been added.

The strength of materials laboratory has added a new Rockwell Hardness Test Apparatus, new extensometers, and a new electric furnace in the heat treatment laboratory together with controller for same.

During the past year there has been added to the engineering laboratory a Skinner Uniflow Engine which was set in the space formerly occupied by a tandem compound McEwen engine driving a twenty-five cycle generator. The new engine is placed alongside a Fitchburg Uniflow installed a year ago at this time. The cylinder of the Fitchburg engine is being replaced by a new cylinder as a flaw developed in the old one, making replacement necessary. A Prosser engine which was located in the northerly end of the laboratory has been taken out and is to be replaced by a new engine of the same type presented by Mr. Prosser. This particular engine has a hollow piston which is supplied with high pressure steam through a hollow tail-rod. The cylinder is jacketed on the head and on the barrel with the idea of securing dry saturated steam throughout the entire stroke. This particular type of engine has shown a Rankine ratio as high as eighty-five per cent when running condensing, which is as high a ratio as has ever been obtained with the most modern turbine condensing at high vacuum. The uniflow engines give also a very high Rankine ratio and with these three engines installed side by side the students will have a chance to experiment on what might be called the latest development toward high economy in engine design.

Arrangements are now underway and shortly there is to be installed equipment for the determination of friction loss of water flowing with such low velocities as are found in the ordinary hot water heating systems working under gravity circulation. There is also being assembled in the laboratory apparatus for determining the maximum rate of flow and the total flow of the ordinary flush toilet so that data may be obtained from which the size of pipe needed in a large office building with a large battery of closets discharging into a common pipe can be determined. Work of this general nature was done some years ago at the Bureau of Standards, the late Professor Whipple of Harvard serving as a member of

(Continued on page 268)

How to be a "letter-man" in 1949

THE game is like the games of undergraduate days.

Line-up mental stature and intellectual courage with physical stature and personal courage. And you have the ingredients of the man to whom industry turns for its big decisions.

It may be reassuring to the man in college to know that the limitations on the number who can take part in industry's game are few.

The field is open — wide open.

The needs are vast.

There's plenty of room for those who can answer the call for candidates with the mental equipment and the viewpoint to tackle the world's problems hard and sure.

Western Electric

SINCE 1882 MANUFACTURERS FOR THE BELL SYSTEM

Recent Books

This department conducted in co-operation with the faculty

AMERICAN CHEMISTRY, *a record of Achievement, the Basis for Future Progress. By* HARRISON HALE, Ph.D., *Head of the Department of Chemistry of the University of Arkansas. Second Edition. Pp. 55. Price $2.50. D. Van Nostrand, New York, 1928.*

Water and sewage, sanitation and medicine, food, fertilizers, textiles and cellulose, coal tar, dyes, fuel, silicate industries, paints and varnishes, rubber, electrochemistry in industry, acids, metals, the World War and American chemistry, American chemistry and the future, are some of the topics considered.

The story of the different industries is told in a popular yet thoroughly scientific and very interesting way, and it is well illustrated with cuts. Facts and figures are freely used, cogently stated, and contrasts made with previous production. Finally, abundant references are given to substantiate various facts mentioned and furnish suggestions for future reading for those interested.

Taken all in all, it is a most fascinating and entertaining book for the layman or scientist, worthy of a place beside Duncan and Slosson, and should be in every high school college and public library in the land.

A. H. GILL.

MECHANICS FOR ENGINEERS — *Statics and Kinetics. By* JULIAN C. SMALLWOOD, M.E., A.M., *Associate Professor of Mechanical Engineering, Johns Hopkins University, and Frank W. Kouwenhoven, M.E., Instructor of Mechanical Engineering, Johns Hopkins University. Published by D. Van Nostrand Co. Inc., New York, N. Y. Pp. 185+x, diagrammed. Price $2.50.*

In contributing this book to the large number and variety of texts on Applied Mechanics the authors, in the preface, state that their purpose is to provide an arrangement and selection of material specially adapted for the instruction of students who are entering courses in engineering in our colleges and universities and to include no more material than can be covered in from 60 to 80 classroom hours.

The book contains a large number of problems, solved and unsolved, illustrating the application of each principle of the subject as it is taken up in the text.

The fundamental definitions and principles are set forth briefly in the opening chapters, followed by a discussion of centers of gravity, of solids and plane areas. The following two chapters deal with the principles of statics and their application in determining stresses in simple frames and structures subjected to plane force systems. The treatment includes the graphical solution of problems in statics by use of the polygon of forces and the funicular polygon. This is followed by a brief discussion of the laws of mechanical friction and some of their applications.

The next seven chapters are devoted to the subject of kinetics as applied to bodies in plane motion. The treatment includes a simple discussion of the fundamentals of Newton's laws, D'Alembert's principle, so-called inertia forces, moments of inertia and other fundamentals, with illustrations in each case of the application in engineering problems. The last chapter deals particularly with compound engineering units and their conversion from British to metric values and vice versa.

On the whole the book is a good elementary text and its arrangement is very well adapted for beginners in the study of mechanics as applied by engineers.

C. E. FULLER.

THE TECHNOLOGY OF LOW TEMPERATURE CARBONIZATION. *By* FRANK M. GENTRY, *New York Edison Company. Published by the Williams and Wilkins Company, Baltimore, Maryland, September 1928. Pp. 399+xvii. Price $7.50.*

As the author suggests in his preface, this book might more properly be entitled "Technology of Carbonization with Special Reference to Low Temperature Carbonization." Covering as it does the fundamental principles of coal distillation and discussing and comparing the products and the yields from both high and low temperature processes, it should be of equal value to those interested in either process.

In recent years there has been published a vast quantity of literature concerning low temperature carbonization. Much of it has been of value, but a larger portion of it has dealt with a single process and has been of the nature of propaganda for that particular process. It is, therefore, with relief that we find the author entirely unbiased in his discussions. Apparently he has reviewed all of the literature on the subject, has sifted the good from the bad, and has presented in a straightforward fashion all that which is good. He has included a bibliography of over four hundred references which will be of value to any who wish further information on any particular phase of the subject.

On the whole it is a book well worth a position on the best of shelves. No engineer interested in the processing of coal can afford to be without it.

T. A. MANGELSDORF.

CHEMICAL ENGINEERING CATALOGUE, 1928. *Thirteenth Annual Edition. By* THE CHEMICAL ENGINEERING CATALOGUE COMMITTEE OF THE AMERICAN INSTITUTE OF CHEMICAL ENGINEERS, THE AMERICAN CHEMICAL SOCIETY, AND THE AMERICAN SECTION OF THE SOCIETY OF CHEMICAL INDUSTRY. *The Chemical Catalogue Company, Inc., New York City. 1107 pages.*

This year, as usual, the catalogue is composed of three sections, each of which is admirably complete in its line. The first section deals with equipment and supplies; the second with chemicals and raw materials; and the third with technical and scientific books. A wide variety of field is covered in great detail, and much information is to be found in nearly every conceivably allied chemical field. Embracing such lines of manufacturing as glass, oil, soap, extracts, cement, leather, paper, sugar and fertilizers, we cannot but marvel at the complete system of indexing which enables the reader to gather all his information as completely as possible.

In addition to this we find listed not only the enormous output of chemicals for use in the industrial market, but since the chemical industries are also large markets for power plant equipment, we find this section fairly complete with descriptions of the various types of equipment available together with much information on conveying and elevating machinery, construction materials, weighing devices and everything which could be of use to the engineer. The committee selected to aid the publication of the catalogue is chosen from men in all branches of industry, and in this way adequate treatment of every phase of the subject is obtained.

The catalogue is thus a compilation of condensed data, standardized and supplemented by a classified index of literature, equipment, supplies, and materials. Its purpose is not necessarily to advertise the products between its covers, but to inform chemical engineers, purchasing agents and works managers, of the state of the chemical market. It does this in an exceptionally able manner and should, without doubt, be on the reference shelf of anyone coming into contact with this field.

H. A. R.

RADIO, A STUDY OF FIRST PRINCIPLES. *By* E. E. BURNS. *D. Van Nostrand, Inc., New York City. 255 pages. Price $2.00.*

Many books have been written for those interested in amateur radio, but we have yet to find one which approaches the quality of the above. It presents the "fundamental principles of electricity as applied to radio" in a masterly fashion. The first three chapters are devoted to the construction of simple and basic radio circuits and with these in mind, the author develops the necessary electrical theory to explain their action. No previous knowledge is assumed and starting with Ohm's Law he develops the principles of electricity in a non-mathematical way. He treats, among others, such subjects as vacuum tube theory, alternating currents, inductance, condensers, rectifiers, and resonance. In short, college electricity right up to the doors of electrical engineering. He employs short, terse sentences which allow easy concentration and are a welcome relief from writers who lose themselves in a labyrinth of words.

The author then covers the more complicated circuits, building them up from simple circuits and principles already explained. Neutrodyne, Heterodyne, and Superheterodyne principles are treated in an excellent manner. The last two chapters are devoted to transmitting circuits and radio measurements. The book is plentifully illustrated with graphs and diagrams.

C. F. E.

TECHNICAL DRAWING. *By* GEORGE EDWIN DRAYCOTT, *Head of the Mechanical Engineering Department, Borough Polytechnic Institute, London, England. Oxford University Press, American Branch, New York City. Pp. 232+viii, illustrated. Price $2.00.*

A textbook on the fundamental principles of mechanical drawing for evening classes and junior technical schools.

It is well suited to the needs of beginners in drafting who have a knowledge of the elements of plane and solid geometry. The orthographic projection used employs the principles of descriptive geometry. However, a very comprehensive knowledge of that science is not required by this treatise and all of the problems may be solved by the so-called "practical geometry" of the secondary or junior technical courses.

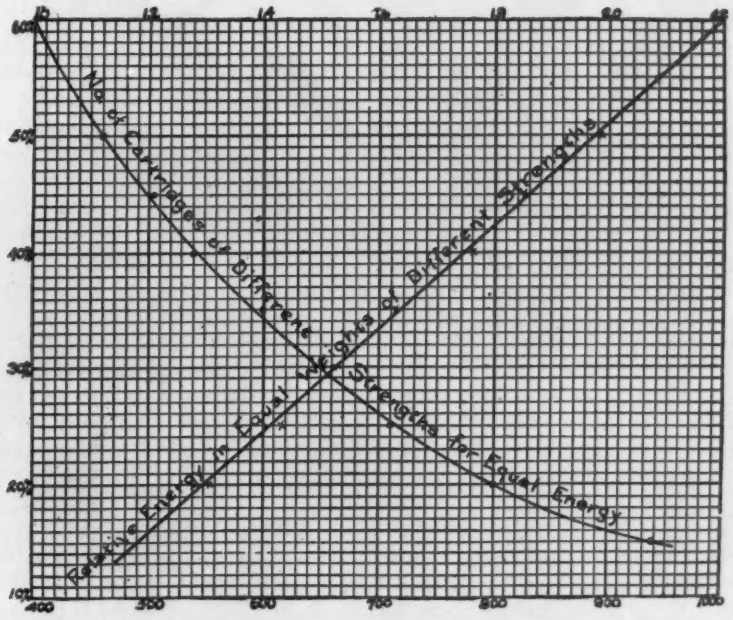
This is one of the few English publications using to any extent the "third quadrant" in orthographic projection and the author observes that this method of projection is being adopted in England to a considerable extent.

A number of excellent exercises in detail drawing are given, but in several instances the technique is not in accordance with the usual American standards of representation. For example, the lettering suggested is not of a variety easily and quickly produced with uniformity by the draftsman, the dimensions are not inserted in a space left in the dimension line and the fraction lines are shown inclined instead of parallel to the dimension line.

However, on the whole, this little book is very well adapted to its purpose.

THOMAS SMITH.

Action of Explosives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Lesson No. 1 of

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Scandinavian Hydraulic Projects

(*Continued from page 247*)

There is also a spillway in the forebay similar to the "glory hole" at Davis Bridge. It is cut through solid rock and is unlined. It is only brought into play by a quick decrease of load, and experience has shown it to be too small in case of a large shutdown.

The thirteen units in this plant are horizontal twin Francis runners set in dead-end penstocks, running at 187.7 r. p. m. Eight units are 12,500 h. p. and the five newer units are 13,200 h. p. The plate steel penstocks which bring the water from the forebay are about 200 feet long.

Lilla Edet has but three units. Two Lawaczeck runners with a diameter of 19.7 feet develop 11,200 h. p. and the Kaplan turbine, 19 feet in diameter, develops 14,000 h. p. All run at 62.5 r. p. m. at a head of 21.5 feet. These runners were chosen after a great amount of discussion about the possibilities of both single and twin-runner Francis units, placed either horizontally or vertically. Before these proposed large runners were finally accepted tests were made on 950 mm. (37⅜ inches) models. The full size Lawaczeck wheels showed an efficiency of nearly 95 per cent and the Kaplan was well over 93 per cent.

The turbines at this plant are described in *Engineering* of April 15 and May 20, 1927.

The draft tube of the Kaplan unit is not a Kaplan tube as that design would have caused too much excavation. Instead, an ordinary quarter turn tube was used. At low loads the difference was slight but at full load the difference amounted to about 2 per cent, with the Kaplan tube giving the better efficiencies.

The universities visited were those at Stockholm and Trondhjem.

The hydraulics, or better hydraulic structures laboratory of the Royal Technical University, has the usual glass walled flume, a river flume, and a large channel in which current meters are rated. This channel is also available for tests on large models.

The turbine laboratory has equipment for testing at low heads, at medium heads, and at high heads. The latter unit is a small pump delivering water to a Pelton wheel. Another testing unit enables the study of cavitation phenomena. This is arranged so as to subject a runner to varying suction and pressure heads, and test it under most any conditions. An oscillograph facilitates observation of the runner.

At Trondhjem there are two laboratories. The turbine laboratory is several years old and the hydraulic structures laboratory is just being built.

The turbine laboratory has equipment for (1) low head testing up to 14.8 feet. (2) medium head testing up to 52.5 feet, (3) high head testing up to 328 feet.

An AC–DC motor generator set provides the DC current necessary for fine speed regulation of the pumps.

The water for the low head unit is supplied by a centrifugal pump with a capacity of 63 sec. feet. This water is delivered to a high concrete reservoir which has a vertically adjustable overflow pipe. This is placed so as to give the desired head, which may be up to 14.8 feet. The water flows from this reservoir through a penstock about 80 feet long and 5 feet in diameter, into the concrete wheel pit, which is similar to the reservoir. The turbines may be set in the wheel pit either vertically or horizontally.

On the side of this rectangular wheel pit opposite the penstock is a recently built weir calibrating apparatus, which will be described later.

From the turbine draft tube the water flows down into a return channel below the main floor level, which takes it back to a measuring weir, from which it drops to the pump sump.

The water for the medium head unit is supplied by a centrifugal pump with a capacity of 15.9 sec. feet at 52.5 feet head. The water is pumped into a vertical cylindrical tank of riveted plate, which is provided with an adjustable overflow pipe similar to the one previously mentioned. From this tank, serving as reservoir, the water flows to an exactly similar tank serving as surge tank. It may do this in either of two ways: through a 230 foot pressure pipe 17.7 inches in diameter or through an equally long open channel which connects the tops of the tanks *i.e.*, water can only flow in the tank when the first, or reservoir tank, is full. The water flows from the surge tank, to the turbine through a pipe 17.7 inches in diameter. The turbine being tested may be placed either horizontally or vertically on either of two floors, or on a between-floor balcony, giving three possible variations of suction head. From the draft tube the water flows into a return channel paralleling the previously mentioned return channel, and similarly equipped with a measuring weir.

The high head equipment is very flexible. A centrifugal pump supplies up to 3.5 sec. feet at a head of 328 feet. This is a single stage pump. Pressure and quantity are controlled by the speed of the pump, by a circumferential valve operating at the tips of the impeller blades, and by an ordinary gate valve. This unit is for testing Pelton wheels. Water returns to a pump sump exactly as with the other units. The return channel is beside the other two. It is much shorter and the weir is much smaller.

Measurements of water quantities are made chiefly by weirs. The existing weirs are all rectangular and sharp-edged. New weirs of a rather odd type are soon to be built in. For the medium and high head units, with small water quantities, the opening is a vertical slot about five times as high as wide. The sides are vertical and the bottom is a semicircle. The weir for the low head unit is to be built as a contracted rectangular weir, but with rounded lower corners. All three of these weir openings are made of bronze, and are not sharp edged, but rounded. This rounding is on a radius of about 4 inches.

In a special return channel there is another measuring device. A movable screen which just fits the cross-section of the channel is carried on a car which moves along the channel on free-running wheels. Electrical contacts along the channel serve to record the motion of the car. The area of the channel is known, and with the speed of the car the water quantity can be figured. The car at Trondhjem does not move freely — it is too heavy — and so the results are not good. This method is very well liked, however, as it is extremely simple and quick, and entails no loss of head as with a weir. The difference in water levels necessary to move a well constructed screen is only perhaps two or three millimeters.

The weirs are calibrated by a device which was built during the past winter. This consists of a dead end length of horizontal pipe, 4.85 feet diameter and 13 feet long, built out from the turbine pit of the low head testing unit. On the under side of the pipe are two rows (lengthways of the pipe) of 9 orifices each. The orifices have a diameter of 4¾ inches, except one of 3.3 inches and one of 2.35 inches. They are spaced 15.7 inches apart. The two rows of orifices are 75° apart on the circumference of the pipe. The orifices have well rounded mouthpieces. The entrance of the pipe itself from the turbine pit is also fitted with a tapering intake.

Below each orifice is a chute that can take the water in either of two ways. These chutes are pivoted on an axle parallel to the center line of the pipe. The pivot is 3 feet away from the orifice. The chutes are swung by a hand lever which has a spring arrangement to snap the chute through the stream quickly. If the water is directed

(*Continued on page 262*)

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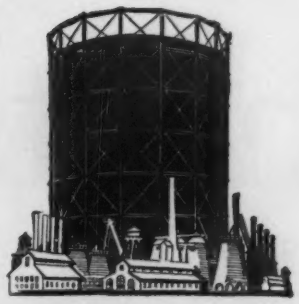

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Scandinavian Hydraulic Projects

(*Continued from page 260*)

down, it flows into a large measuring basin, previously calibrated by weighing. If it is directed up, it is by-passed to one of the return channels and flows over a weir to be calibrated.

Prony brakes are used to load the turbines. A novel brake, consisting of a closed circuit gear oil pump whose casing was connected to scales through a lever, was found to function poorly. (It was returned to the manufacturer for improvement. A timely fire at the factory destroyed the brake and everybody concerned was greatly relieved.)

An interesting piece of testing is being done in this laboratory. The penstock of an 1,150 feet head plant was found to be too weak at the joints. A piece of the penstock was brought into the laboratory and tested. This section has two joints of different design and an expansion joint. The yield of the joints is measured by securing mirrors to the two halves. A reflected beam of light indicates on a scale. As the joint is stressed the two halves of the joint undergo an angular deflection which the reflected light beam promptly shows. The two ordinary joints showed too much deflection at a head of 1,320 feet and the expansion joint is going to be tested up to 3,280 feet.

The hydraulic structures laboratory is now under construction. It will not be a large laboratory. It is hoped to have it ready for work this fall (1928).

Two centrifugal pumps, one pumping 2.3 sec. feet and the other 1 sec. feet, supply water to a high level reservoir, where sensibly constant head is maintained by weirs with a total length of 105 feet. The spill goes back to the sump. The water to be used flows down through a short section of vertical pipe with a gate valve in it to a stilling chamber, and then over a rectangular surpressed measuring weir to the river flume. An exactly similar arrangement from the other end of the high level reservoir delivers water to a glass-walled flume.

The river flume is of sheet steel, 40 feet long and 6.6 feet wide. The outflow is through a rectangular opening in the end wall, controlled by a vertical lift gate on a screw spindle.

The glass-walled flume is of the same length, is 19.7 inches wide and 25.5 inches deep. The outflow is through vertical shutters, similar to turbine wicket gates, and then a gate as in the river flume.

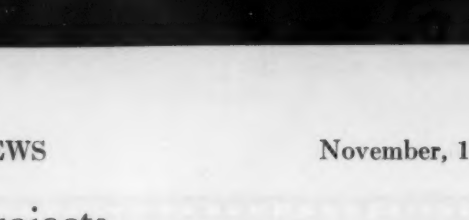
A small zinc-lined flume 20 feet long and 3.3 feet wide and 10 inches deep is supplied with water by a portable pump and will be used for demonstration work. Another tank 5 feet by 8 feet is used for wave action study. There is no flow in this tank. Waves are "handmade" with a piece of board.

In the end of the laboratory opposite the flumes there was a model of the harbor of Berlevaag in northern Norway. Experiments have been made to determine whether a new mole or an extension to the present existing mole are necessary. The model tests showed that a new mole is necessary.

Wave heights were measured at the harbor entrance of this model by photographing the waves as they moved along a vertical sheet of zinc which had coördinates marked on it. This sheet caused no disturbance as it was placed in the direction of wave travel. Inside the breakwater, wave heights were measured by chalk-covered glass rods standing perpendicularly in the model.

(*Continued on page 264*)

Steel Sheets



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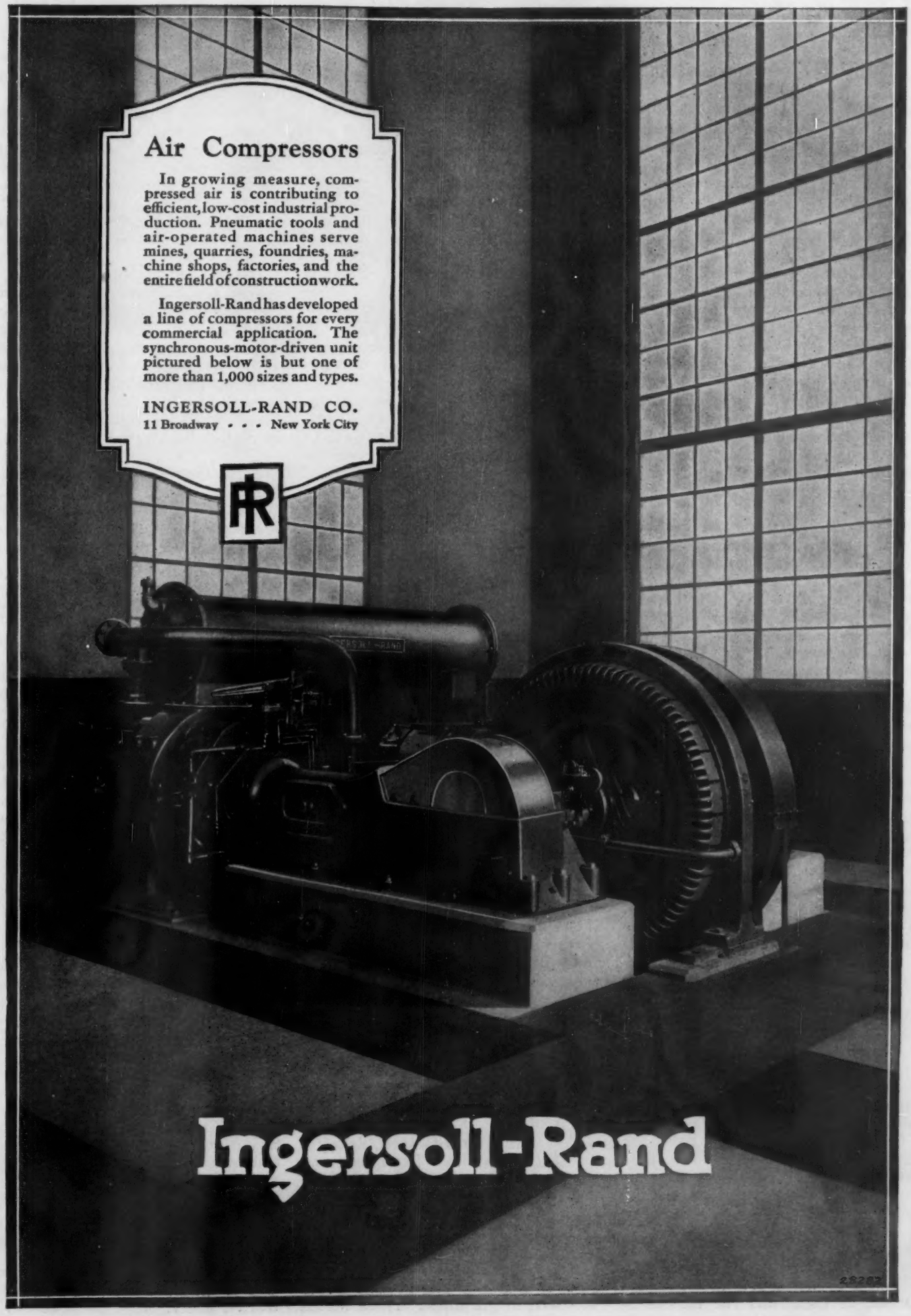
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Scandinavian Hydraulic Projects

(*Continued from page 262*)

The chalk was washed away up to "high water mark," which was later measured.

A total of five turbine manufacturers were visited. Two of these were in Oslo, Norway and three in Sweden.

In Oslo, the works of Kvaerner Brug and of Myrens Verksted were visited.

The former have a very interesting way of building up turbine runners. The blades are of pressed steel. They are cast into the upper hub ring, which can then be machined. The lower, or outer ring, has been previously made and machined both inside and out. Tongues on the blades fit through holes in the outer ring. The blades are then welded to this ring.

The advantage of this method is that the stresses set up in the blades are less; the blades are thinner, smoother and more exact; the lower ring is smoother and as the water velocities are high at this point the loss is less.

The testing laboratory of this firm is quite simple. It consisted of an open pit setting for testing wheels under heads up to 16.5 feet. By putting a cover on this pit heads up to 53 feet can be used. The water quantity, which is at times as high as 18 sec. feet, is measured by orifices. Load is applied with a prony brake.

This firm has a water power station where high head testing up to 330 feet can be done. Pelton testing is done here.

Myrens Verksted has very recently been acquired by Kvaerner Brug. Francis wheels are made here with forged blades cast into both rings. Several Pelton wheels of various sizes were seen in the shops. One very large gate valve, operated by a hydraulic piston, was being assembled. I was told that this type of valve has always given good service without any trouble from vibration or pitting.

The shops of Verkstaden, Kristineham, were the most interesting ones visited. This plant is devoted entirely to the manufacture of water turbines and regulators. They also have a very good laboratory for runner study and for cavitation research.

In their shops I saw the hubs, or bosses, for the two 15,000 h. p. Kaplan turbines to be installed at Munkfors. The blades were not there, as they are of stainless steel and are cast in a different shop. The speed ring and guide vane castings were there and the wicket gates were being worked on.

Verkstaden have the sole Swedish rights for Kaplan turbines. They have had 38 ordered, of which 29 are completed and running. The first and largest of these was the turbine at Lilla Edet, with 11,200 h. p. The Munkfors wheels will be 15,000 h. p. but at a 50-foot head.

The laboratory at Kristineham was a pleasure to visit. The testing flume, where designs are improved and characteristics are studied, is equipped so as to give a one meter head. All testing in this flume is done at this head, and on 250 mm. (10-inch) models. A prony brake loads the wheels. Floats in the head and tail water actuate graduated rods which move relatively to each other and give the head by a single reading. The quantity is measured with a contracted weir having edges rounded on a large radius. All the scales and dials are conveniently arranged so that one man can do the testing alone.

The cavitation equipment consists of a closed pump-turbine circuit so arranged that various pressure and suction heads can be used. Glass plates in the draft tube of the turbine, and lighting with an oscillograph enable observation of the runners. Load is supplied with an Alden dynamometer; quantity is measured with a Venturi meter; and pressure gauges give the heads.

This laboratory is described very thoroughly in *Engineering* for September 24, October 1 and 8, 1926.

If a new turbine, unlike any predecessors, is to be built, 250 mm. models of it are first tested. The design is thus improved and the efficiency improved. When a final design is attained, a larger runner is built — perhaps 500 or 600 millimeters — and this is tested in an outdoor flume with greater head and flow. From this test, the efficiency of the full size runner is predicted with the help of Moody's formula.

The cavitation equipment allows of exact determination of the maximum allowable suction head under which a runner may operate without pitting and without losing in output. This equipment is described in the *Canadian Engineer* of April 13, 1926.

The quality of the work done at Kristineham may be judged from the fact that they guaranteed a maximum efficiency of 92 per cent for the new Kaplan turbines at Lanforsen. These are 13,000 h. p. wheels at 30 feet head.

Aktiebolaget Finshyttan was the second turbine manufacturer visited in Sweden. They build Lawaczeck and Dahl turbines, as well as Francis and Pelton units.

The Lawaczeck runner is a propeller runner and is faintly similar to a Francis wheel with fewer blades and no outer ring. They usually have 5 or 6 blades. One small wheel with 8 blades was seen in the shops. These wheels are made with separate blades. The blades do not overlap.

The Dahl turbine is a propeller runner with the ends of the blades curled up. The water leaving the blades has less axial speed and more lateral speed, which allows of a much shorter draft tube. The wheel has also good part load efficiency. Finshyttan have already installed a few of these runners.

The laboratory at Finshyttan is used to test runners of varying sizes. The available head varies from 4.6 feet up to 13.2 feet. The water supply and the head are natural. The open flume setting allows of only vertical placing of the model. Loading is with a prony brake. Heads are measured with floats. Water quantities are measured by the flow height through a calibrated opening. This calibration was by a large volumetric tank situated outdoors.

Runners of 500 mm. (19.7 inches) are usually used, under heads of about 8.2 feet. Much larger runners can be tested, however.

Draft tubes are usually made of wood, built up of small pieces. If any particular draft tube is to be used a great deal it is made of metal — usually cast iron.

They hope to build a new testing laboratory at Finshyttan which will have facilities for research with draft tubes.

The last manufacturer visited was Nydquist and Holm in Trollhättan.

They have two testing plants. The indoors laboratory is for testing small runners at 3 to 4 feet head. It is here that designs are improved.

The larger semi-outdoor stand has an available head of 23 feet and a maximum water quantity of 160 sec. feet.

In Copenhagen, on my way back to Berlin, I visited the Technical University in the hope of seeing their hydraulic equipment. The professor in charge was away and the laboratory was closed, and so I saw nothing. I did learn, however, that the present hydraulic laboratory is rather small — it consists of one small flume, used largely, I presume, for demonstration.

In closing, I want to tell how satisfied I feel with the whole trip. I have nothing but praise for the way the Scandinavian engineers are doing things, and for what they are doing. And thanks, too, for the splendid way in which I was everywhere received.

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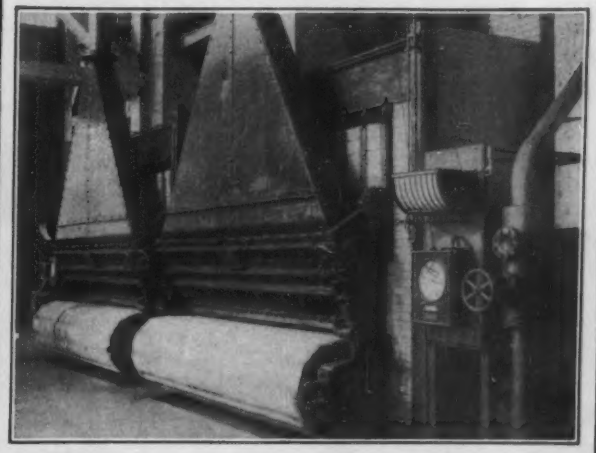

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Emission Cathodes

(*Continued from page 252*)

gas. Unfortunately the tungsten carbide tends to make the filament brittle, so that only a limited amount of it can be used. It has some advantages, however, other than the reduction of thoria. The evaporation of thorium from carbide appears to be a trifle slower than from pure tungsten, and the carbon which slowly evaporates probably helps to remove harmful traces of gas from the tube, by carrying and depositing it on the cool glass walls of the tube.

Cæsium Filaments

The theory of emission from filaments has been extended within the past few years to the production of the cæsiated filament by Langmuir and Kingdon. It appears to be true that electrons escape more readily from atoms having larger atomic volumes, such as thorium and the alkalies. Cæsium has a very high atomic volume and the electron emission from it is therefore extremely high. Like all the alkalies, it is far too volatile to incorporate in a filament, but its very volatility is taken advantage of in the cæsium tube. In this type metallic cæsium is present on the walls of the tube; and at room temperatures the vapor pressure of the cæsium, although low, is sufficient to keep the tungsten filament covered with adsorbed cæsium atoms when the filament is run at about 700° K. This is a very low temperature, but if the filament is first covered with an atomic layer of oxygen (by heating it in a low pressure of the gas) the cæsium will adhere more strongly. The oxygen has a strong attraction both for the underlying tungsten and for the cæsium, and so acts to hold the two together. Such a filament can be operated at over 900° K. The emission from this cæsiated filament, if the bulb is kept at 20° C., is over 100 milliamperes per square centimeter, or more than 250 milliamperes per watt.

Oxide-Coated Cathodes

Another type of material that is coming more and more into use of late is the oxide or oxide-coated cathode. Wehnelt observed in 1904 that a little calcium oxide on a platinum filament gave very high electron emission. Since then a number of investigators, notably Davisson and Germer, have studied the emitting properties of the oxides of the alkaline earths. Barium oxide produces the most highly emitting material, but for practical reasons a mixture of barium and strontium is ordinarily used. As is so often the case, the technical application of this material has progressed beyond the theoretical solution of the reactions and conditions involved. It has become fairly evident, however, that the activity of these oxide coatings depends upon a reduction of part of the material to metal. Presumably, this metal is adsorbed on the oxide so that here again we have, apparently, a monatomic or monomolecular layer functioning as the active emitting agent. Recent investigations indicate that the reduction of the alkaline earth oxides can be brought about in two ways: first, by the use of a base or substrate which at high temperatures (1300° or more) will react with the oxides to form some alkaline earth metal and presumably metallic oxide, and second by a voltage discharge between the oxide-coated cathode and the anode, whereby the poorly conducting oxide is electrolyzed with the liberation of oxygen and formation of metal in the oxide-layer.

(*Continued on page 268*)

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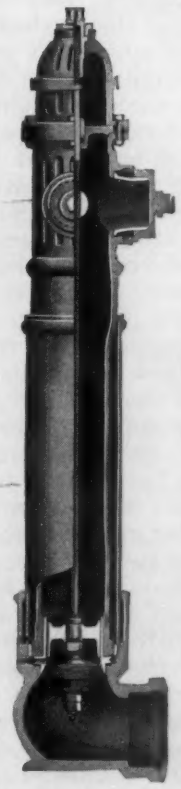

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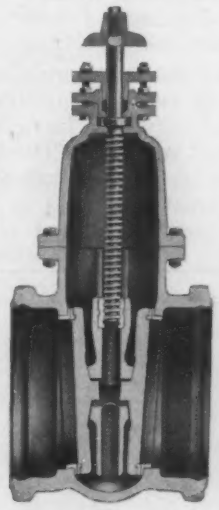

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Emission Cathodes

(*Continued from page 266*)

Just what part the unreduced oxide plays in the emission is yet to be determined. It may be that it acts in the same way as oxygen acts on tungsten in cæsium emission, that is, to hold the active metal on the surface. In such a case one can imagine the formation of a suboxide of, say, barium on the surface (as *Ba-O-Ba*), the atom of oxygen from a molecule of barium oxide acting as a binder to hold the extra atom of metallic barium on the surface. The oxide coatings are usually formed by heating coatings of the carbonates in vacuum; and it is possible that by this method a porous layer is obtained which can adsorb a very great quantity of metal and so yield a very large area for emission. This corresponds to the theory of the activity of absorbent charcoal due to its state of great subdivision and its consequent great adsorbing area.

Oxide-coated cathodes are apt to vary considerably in their activity unless a rigid method is followed in their production. They have the advantage that they operate at low temperatures (about 1200° K.), and that they can be prepared with large surfaces, so that very large emission currents can be obtained. The usual form of these larger cathodes is a metal cylinder or cup coated with the oxides and heated from within by a stout tungsten spiral filament. The emission efficiency averages about fifty milliamperes per watt, but it will not be surprising to see this value greatly increased.

In conclusion it may be said that the development of these various types of electron emitters is one of the things that has made possible all the great family of radio transmitting and receiving tubes that have come on the market of late years. The story has not yet been completed, and we may expect to see great advances in the coming decade in this art and science.

Departmental Notes

(*Continued from page 256*)

the committee which undertook this work in connection with the bureau.

The method of testing which is to be used here differs entirely from that used by the Bureau of Standards inasmuch as the closet is to discharge into a vertical standpipe, which has connected with it at the bottom a Bristol recording gauge with tuning fork timing device, which will give on one dial the pressure due to the hydrostatic head in the pipe at any given time, the pipe being closed at the end and calibrated for capacity. The reading from the gauge makes it possible to calculate the quantity discharged up to any given time and also the rate of discharge at any instant. It is felt that this work will be of value to the men in Course XVII as well as to engineers in general, and we are assured that the various manufacturers of plumbing supplies will gladly furnish samples of the various fixtures in common use.

During the summer an independently fired superheater located in the basement of the laboratory has been taken out, two water meters removed, and thereby quite a space has been obtained for experimental work.

The machine shop located on the second floor, which has been run as a repair shop and a shop for turning out specimens required in the strength of materials laboratory by men working on graduate or undergraduate theses has been removed to the basement of Building 1 in what was formerly the department storeroom. The space freed by the removal of the shop has been taken over by the Mimeograph Department and by the Alumni Office. Space for the storage of tanks, scales and other equipment which the department has to keep in storage for the use of students who conduct theses outside of the Institute has been secured by taking the northerly end of the locker room in Building 5.

During the past summer an Akimoff Balancing Machine automatically locating and designating the amount of balance weight needed to an inch ounce has been purchased from the Tinius Olsen Company and is now being installed in the basement of Building 5 alongside of a Norton Balancing machine. Professor Buckingham is planning to have both of these machines available for regular laboratory work during the coming year and to offer for graduate students some special work on the Akimoff Machine.

In the gas engine laboratory the usual work of development has been carried on — one item particularly worthy of mention is the development of a single sleeve engine which has been brought out completely in this laboratory. A description of this engine is shortly to appear in the technical press. Considerable work has also been done by the laboratory staff in assisting manufacturers in development problems, Professor Fales having been called to a number of the laboratories of automobile engine manufacturers who have had problems on which they desired his assistance. Immediately following the race at Rockingham Park a number of the cars which were in the race were shipped down to the Institute so that students might have an opportunity to examine them.

Enrolled in the department during the last year there were thirteen candidates who received the degree of master of science and fifty-seven successful candidates who received the degree of bachelor of science. During the past summer eight men in addition to the above have completed the requirements and have been recommended for the bachelor of science degree.

Although in some parts of the country business was considered somewhat slack last spring the demand for mechanical engineers seemed to be as great or if anything greater than usual. Ninety per cent of the men were placed before April 19, and those who had not definitely accepted a position at that time had numerous opportunities from which to select. In general the men received pay at the rate of one hundred and fifty dollars per month. One man who had had some outside experience before coming to Tech received two hundred and fifty per month. If the prosperity of the country continues there is every reason to believe that the demand for the man graduating in 1929 will be as great as the demand in 1928.

In addition to the regular work of instruction of both graduate and undergraduate students some members of the

(*Continued on page 270*)

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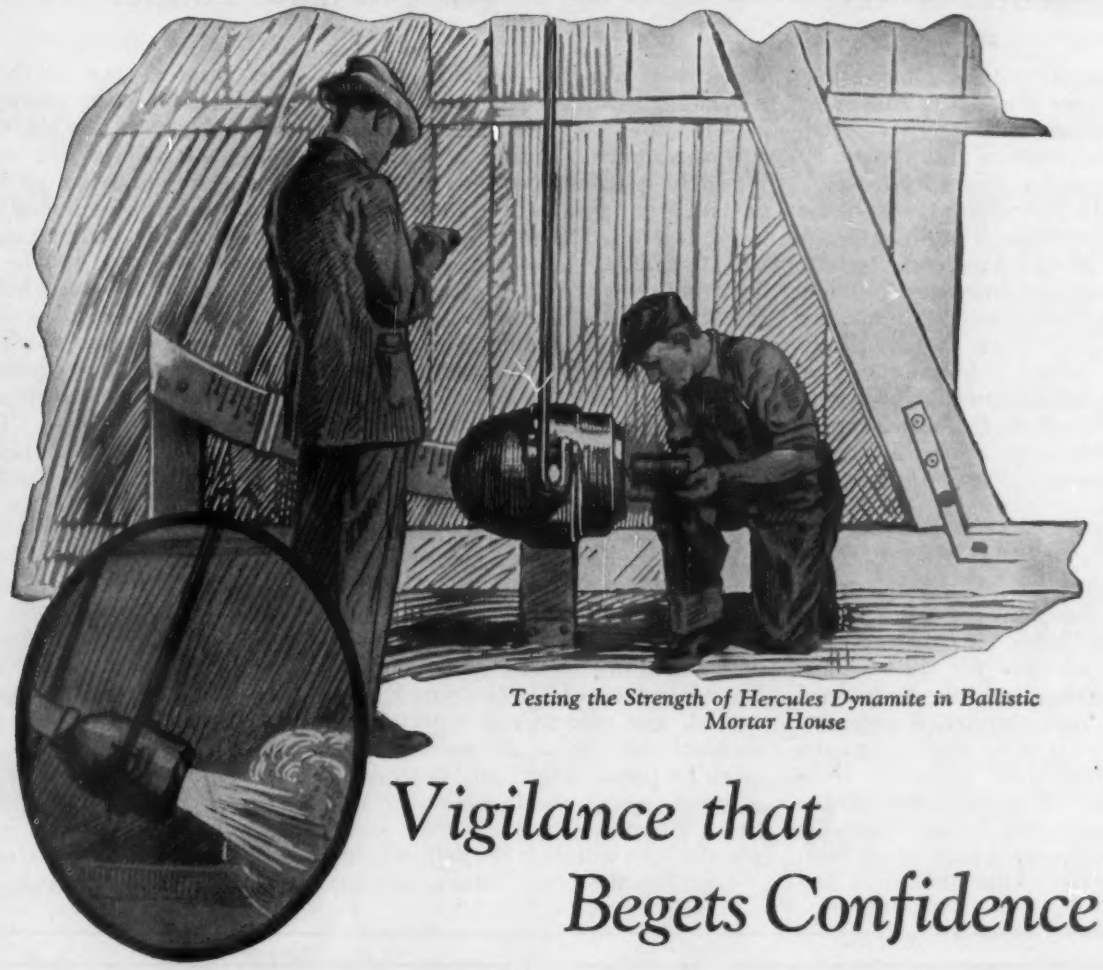

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Departmental Notes

(*Continued from page 268*)

staff have been carrying on some rather lengthy problems in research under the general direction of the Division of Industrial Coöperation and Research.

During the past summer Prof. R. H. Smith and Mr. Zavarine attended the National Metal Exposition held under the auspices of the American Society for Steel Treating, American Welding Society and Institute of Metals, at Philadelphia, October 8–12. Prof. T. H. Taft visited a number of the large turbine manufacturers during the past season. Prof. R. G. Adams represented the Institute at the Portland Cement Association Conference at Philadelphia.

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A New Fog Light which, under severe tests, has guided pilots through 6,000 feet of dense fog, is being installed by western air lines. An ordinary projector and lamp is used to send the rays through a patented lens, which is made by dissolving salts of gold, silver and platinum in a molten glass. The particles of the metals refract and reflect metallic amber-colored rays which have been picked up thirty miles distant in fog.

The Holland Tunnel

(*Continued from page 245*)

When the jam is cleared, the officer will change the red light to green by pressing the "go" button, and traffic will be resumed.

Should a collision occur, the officer nearest the accident will press the "stop" button, thereby stopping incoming traffic. If the car which collided requires aid to remove it from the tunnel, the officer will call the chief supervisor by telephone. The operator will then notify the crew of the wrecking truck assigned to that particular tunnel, at the same time requesting his assistant to illuminate the yellow lights from the exit of the tunnel to the point of the accident.

The illumination of the yellow light will inform all officers between the accident and the tunnel exit that the emergency truck is coming in against traffic, and for them to instruct the outgoing traffic to keep to the right of the white line. After the wreck is removed, the officer who reported the accident will change the red signals to green by pressing the "go" button and will notify the chief supervisor that the accident is clear. The chief supervisor in turn will clear the yellow lights.

Should a fire occur from a collision, the officer nearest to the trouble will press the fire alarm button. The pressing of the fire alarm button will change all signals behind the station to red, thus stopping incoming traffic, and at the same time will illuminate all the yellow lights beginning with the station beyond the fire to the tunnel exit. Pressing the fire alarm button produces an indication located in the chief supervisor's office, and also in each of the fire truck garages, where an annunciator indicates the station from which the alarm was sent in. The indication of the yellow light being the same in this case as when the tunnel had a simple collision. At the sound of the alarm the fire fighters, located at the exit of the tunnel in which the fire is present, will proceed into the tube.

As soon as the supervisory operator receives the fire alarm indication on the traffic board, he operates the switch mounted alongside of the "Stop Engine" sign. This will cause the "Stop Engine" signal to be illuminated in the tunnel wherever the red signal light is burning.

As soon as the fire is extinguished and the fire fighters are ready to return

(*Continued on page 272*)

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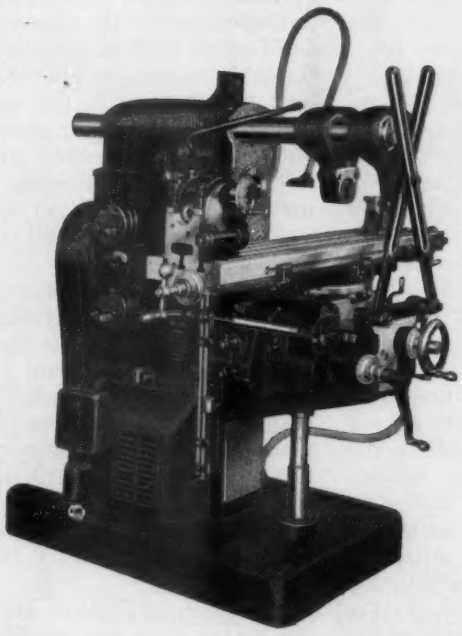

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The Holland Tunnel

(*Continued from page 270*)

to their garage, the traffic officer that sent in the alarm will notify the chief supervisor that the fire is out and that the emergency truck is leaving the scene. The supervisor is the only person who can reset the fire alarm following the information from the traffic officer. He will reset the fire alarm station from his traffic signal board, followed by extinguishing the "Stop Engine" signal, then resetting the "go" button, allowing all traffic to proceed. When the operator resets the fire alarm station, the yellow lights will be automatically extinguished.

A small rectangular-shaped box located between the traffic signal control buttons and the traffic sign, and projecting out from the wall of the tunnel, contains a yellow light near the top and a blue light near the bottom. The purpose of this yellow light has been explained above. The blue light indicates two things: first, when it blinks, the traffic officer is to answer the telephone, in other words, it acts as a telephone bell; second, when the blue light is out, the control supply of that particular section of relays is open, consequently this light burns normally.

In the tunnel wall beside the traffic signal buttons is located a cabinet wherein are mounted the relays used for the traffic signals and telephone, and a transfer relay used to automatically transfer the voltage supply for the signals from alternating current to direct current. The traffic signals are normally supplied from the same source as the lights from the tunnel, that is, every other signal is fed from the New York feeder, whereas the other group is fed from a New Jersey feeder. In case of an emergency requiring that a section of the tunnel lighting circuit be temporarily broken, the signal lights are supplied by a storage battery system.

All changes in the traffic lights made by the traffic officers will be registered on the traffic signal board located in the supervisory room in the New York Administration Building. This board is composed of two steel cabinets formed by sheets of one-eighth-inch "stretcher-level" steel having an inner and outer door at the rear. The purpose of the door is to obtain access to the interior of the cabinet for wiring and mounting of apparatus. Upon the door are mounted the relays used in conjunction with the signal equipment. Figure 4 shows each outer door whereon relays used for twenty-four signal stations are mounted. The relays for the remaining stations are mounted on a swinging door within the cabinet.

Across the front of these cabinets are two tiers of lights and switches, the upper tier representing the signal station of the north tunnel, and the lower tier representing the signal station of the south tunnel. For each station there are four signal lamps and four switches as shown in Figure 5.

The small switch located between the first and second rows of lights ("stop" and "go" signals) is for the operator's use. When it is thrown to the up position, it will operate all red signals from that station back to the entrance of that particular tunnel. When this switch is thrown to the up position, the traffic officer in the tunnel cannot operate the signals until the switch is turned to the down position by the supervisor. Such an operation gives the supervisor full control of the signals in the tunnel.

Carbon Monoxide Recorder and Metering Equipment

Located to the left of the main supervisory control board is another switchboard known as the carbon monoxide recorder and metering board. Upon this board are mounted fourteen graphic recorders, seven for each tunnel. These record the amount of carbon monoxide in the exhaust gases. In addition to recording, this apparatus also sounds an alarm when the mixture of exhaust gases has over 3½ parts of carbon monoxide to 10,000 parts of air, at the same time illuminating the "CO" lamps located in the trough of the mimic tunnel on the main supervisory board. This board has also mounted upon its face two graphic recording wattmeters, one used to indicate the total amount of power used from the New York feeders and the other to indicate the power used from the New Jersey feeders. These meters are operated by transmitters located in the respective land ventilation buildings.

Tunnel Lighting

The tunnel is illuminated by lamps spaced every twenty feet, except at the entrances where they are spaced every ten feet to help in counteracting daylight. Each lamp is placed in an enameled reflector set in the wall near the ceiling of the tunnel, and is screened with a special frosted glass panel. After many experiments had been made this combination was selected to secure well diffused illumination and to prevent glare.

Safety was also considered in working out the lights that illuminate the tunnel. Every other lamp is supplied with power coming from a New York feeder and the remainder with power coming from a New Jersey feeder. The plaza lighting has not only been laid out with the idea of utilizing the light to the best advantage, but to present an artistic appearance. Here the traffic problems were analyzed to the fullest extent.

The Holland Tunnels are illuminated far better than any similar structures of their kind in the world. The lighting installation stands as an example of an accomplishment made possible through the most careful analysis of all the problems and through the coöperation of many engineers who have taken nothing for granted.

Conclusion

The Holland Tunnel will revolutionize vehicular traffic across the Hudson River, as it is the first fixed crossing for such traffic between New York and New Jersey. The opening of the tunnel marks a new era in vehicular transportation, as the research work carried out in connection with the planning of the ventilation system for the tunnel will serve as a basis for the ventilation of future vehicular tunnels, and will make possible the economical construction of crossings at places where heretofore they have appeared economically impracticable.

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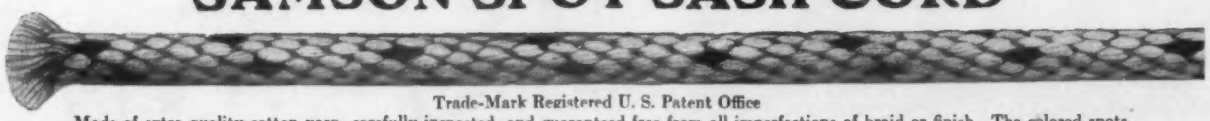

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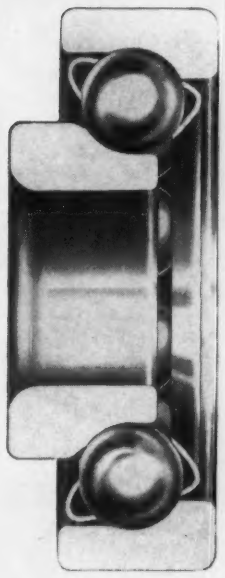
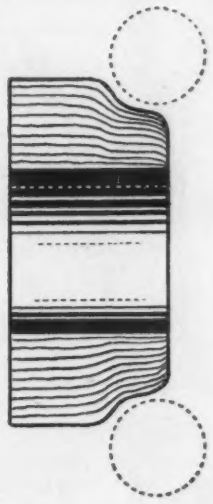


Half-section of New Departure Ball Bearing showing the contact between the balls and raceways.



Sketch of inner race after upset forging process. Note direction of fibre flow. Actual specimen does not show flow sufficiently clear to be properly reproduced.

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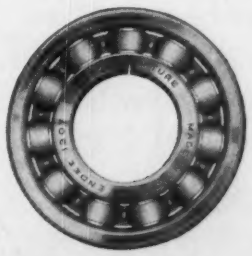

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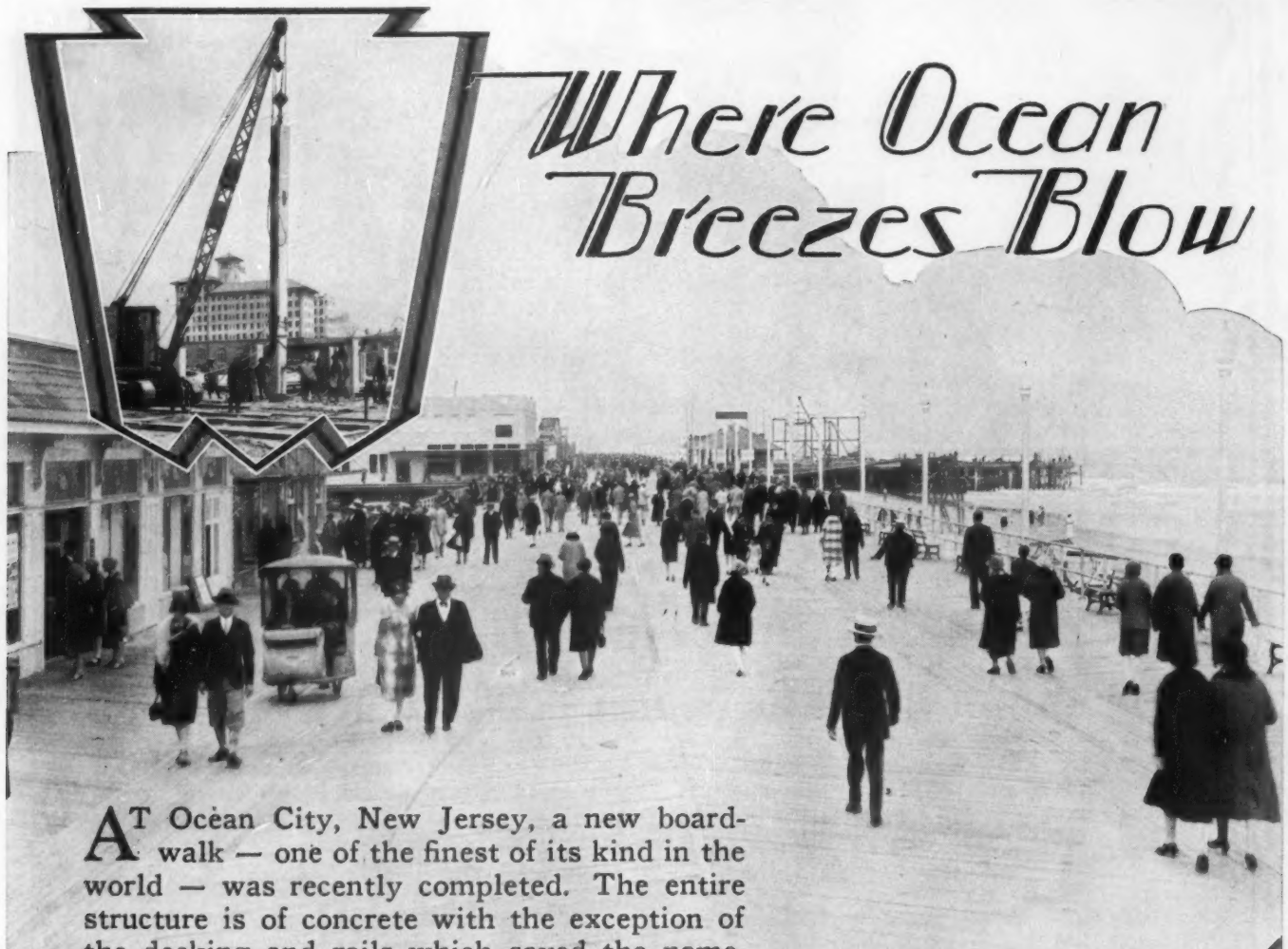

AT Ocean City, New Jersey, a new boardwalk — one of the finest of its kind in the world — was recently completed. The entire structure is of concrete with the exception of the decking and rails which saved the name, boardwalk, from becoming concrete walk.

Supporting this sea shore promenade are 780 concrete piles, each 18 inches square, 32 feet in length and sunk 24 feet in the sandy beach. Each pile, which weighed more than six tons, was lifted and located with a Koehring Heavy Duty Crane.

Another feature of this construction was the speed and adaptability of the Koehring Crane in setting the piling. The last pile was sunk four days ahead of the specified schedule. The entire contract was completed and accepted one day before the time limit.

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Entrance examinations are held at the Institute in September. In June applicants will be examined by the College Entrance Examination Board in Boston, New York, Philadelphia, Chicago and many other cities in America and Europe. A circular stating times and places is issued in advance by the College Board.

Graduates of colleges and scientific schools of collegiate grade, and in general all applicants presenting satisfactory certificates showing work done at another college corresponding to at least one year's work at the Institute, are admitted without examination, to such advanced standing as is warranted by their previous training.

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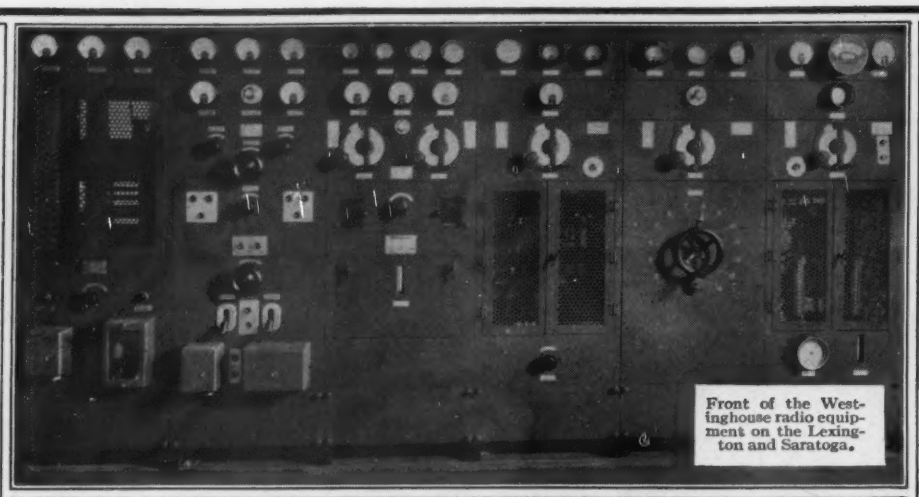
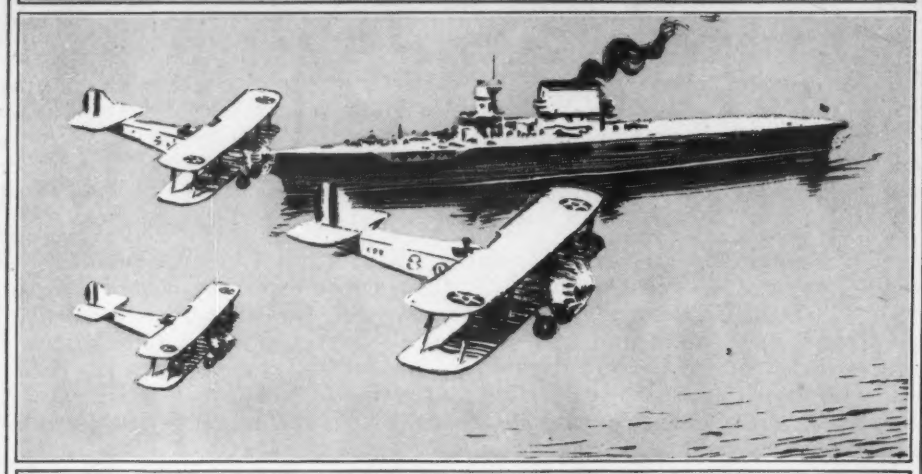
University of Pittsburgh, '27

O. B. GUNBY
Engineer, Photo Phone Division
Dickinson, '27

JOHN COLEMAN
Radio Engineer
Carnegie Institute of Technology, '23



Front of the Westinghouse radio equipment on the Lexington and Saratoga.



YOUNGER COLLEGE MEN
ON RECENT WESTINGHOUSE JOBS

C. J. BURNSIDES
Design of Transmitters
South Dakota School of Mines, '24

C. J. MADSEN,
Radio Installation Engineer
University of Nebraska, '26

S. V. PERRY,
Engineer, Loud Speaker Group
Queens University, '23

H. I. METZ
Development Engineer
University of Pittsburgh, '26

Radio Directs the Navy's Flyers . . .

Where do young college men get in a large industrial organization? Have they opportunity to exercise creative talent? Is individual work recognized?

. . .

AIRPLANE carriers are a recent development in naval history — and they have a communication problem that calls for the engineering resources of an organization which has shown it can make radio history.

Complex maneuvers are directed, scouting expeditions controlled, and far-flying planes recalled — by radio.

On the U. S. Navy Airplane Carriers "Lexington" and "Saratoga" the situation is met with crystal control transmitters designed to send on different wave lengths. Each plane's receiving set has its own wave length. A turn of the dial on the transmitter selects the wave length corresponding to that of the plane to be reached with a message.

Radio equipment on the "Lexington" and "Saratoga" was designed, built, and installed by Westinghouse — the organization which in 1920 established KDKA, the pioneer radio broadcasting station of the world.

. . .

Opportunities to do the history-making things in engineering fall naturally to an organization with a record for making history in its field. And Westinghouse, quite as naturally, offers powerful attractions to young college men whose initiative and enterprise fit them for history-making tasks.

Westinghouse

Aerial view of the tip of Manhattan Island, New York City

THE SKY IS THE LIMIT!

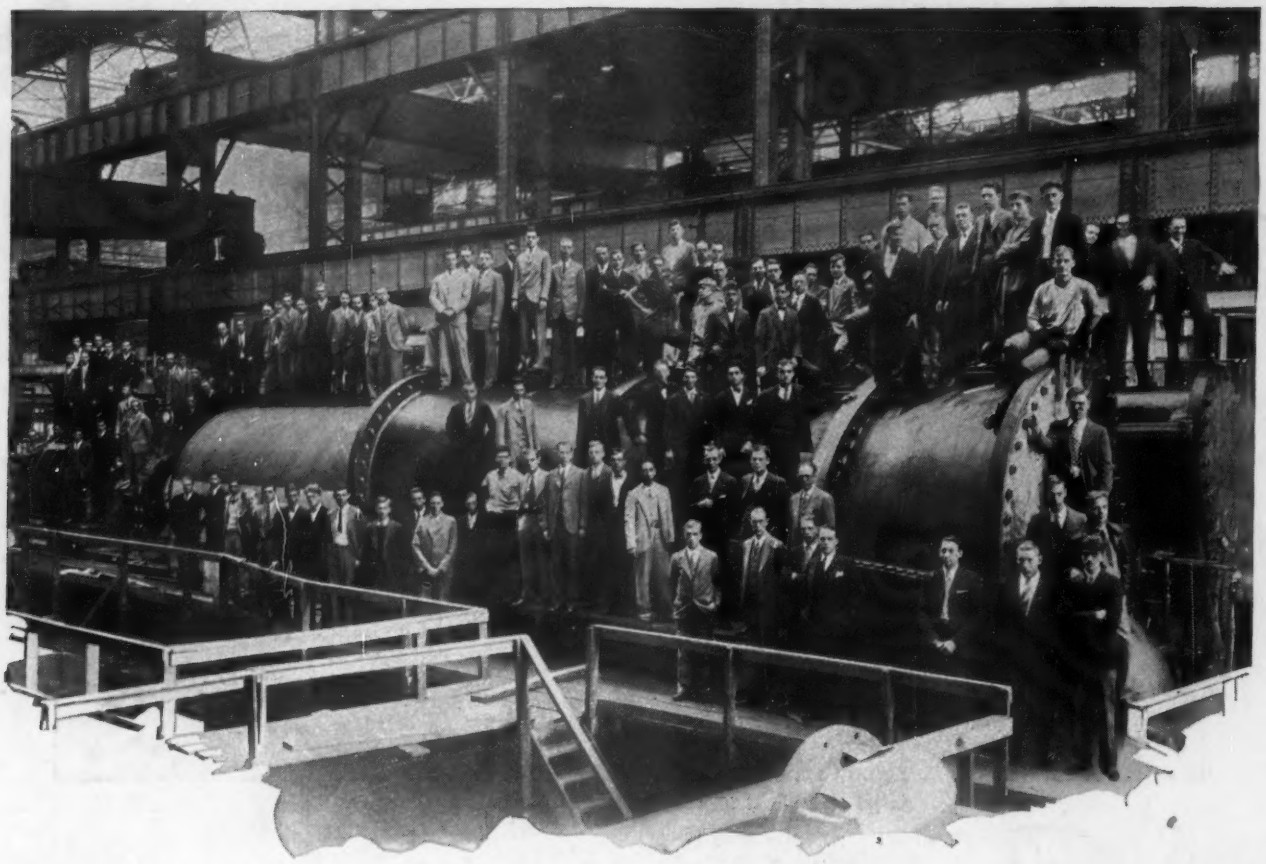
BEFORE the elevator removed this limitation, five stories was the height limit of buildings. Upper floors were undesirable—people didn't enjoy the long, hard climb to roof-tree quarters.

Today there is no restriction. Upper floors are preferred for their light, ventilation and splendid view. Elevators have made buildings of any height practicable. The only limit is in the construction of the building itself.

For more than 75 years Otis has led the way in Vertical Transportation—changing the skylines of the nation.

OTIS ELEVATOR COMPANY

Offices in All Principal Cities of the Worla



"On Test"

FROM all parts of the world they come each year—selected college graduates to begin their duties as G-E Test men.

From giant turbines to tiny relays, millions of dollars worth of equipment is tested by these young engineers during their training period.

This rigorous training, embracing practically every phase of electrical engineering, better fits them for their life work whether it be in the General Electric organization or elsewhere.*

But it is not only electrical knowledge which is gained "on test". Here men also find inspiration which prepares them for leadership in this electrical age.

*Conservatively, 90 per cent of General Electric test course "graduates" are engaged in electrical and allied industries; more than two-thirds of this number remain with the General Electric Company.

95-605 DH

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